PIGEON LAKE

watershed management plan 2018

appendices

Pigeon Lake Watershed Management Plan Steering Committee
Issued Aug 24, 2018

Working Together for a Healthy Watershed, Healthy Lake, and Healthy Community

TECHNICAL SUPPORT

(RECOMMENDED CITATION)

Pigeon Lake Watershed Management Plan Steering Committee (plwmp.ca). August 2018.
The Pigeon Lake Watershed Management Plan 2018 – Appendices.
Pigeon Lake Watershed Association (plwa.ca) and Alliance of Pigeon Lake Municipalities (aplm.org)

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ACKNOWLEDGEMENTS

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APPENDIX A: IMPLEMENTATION PRIORITES

PLWMP 2018 Implementation Priorities

Updated 2018 - 0

Implementation priorities from the Pigeon Lake Watershed Management Plan-2018 found in the attached table. Notes regarding the use and interpretation of the tables are as follows:

1) PRESENTATION ORDER: The forty-six recommendations of the PLWMP 2018 are presented below sorted first by lead agency and second by time frame. This presentation of the recommendations sorted in this order is intended to facilitate the annual review of action priorities by each "Lead Agency" (see Roles column).
2) OBJECTIVE: Coloured Boxes in the first column visually relate to the eight objectives described in the main body of the Plan document and are repeated below.
3) TYPE: Three types of actions or recommendation are identified in the main body of the report and described on page 17. They include Policy, Community Action and Technical/Scientific.
4) ROLES: Roles are allocated into two types: Lead and Support. Being a "Lead" means that this agency or group is best suited to track and organize resources to make progress on the recommendation. Achieving outcomes with Lead organization internal resources is not necessarily expected or required. A Lead agency needs to work with organizations or resources can accomplish the identified outcomes. Descriptors for lead roles are as follows:

Roles:	Roles:	Roles:
Mun= Municipalities	PLWMP= Steering Committee	TS= Technical Specialist/ Researcher
SV= Summer Villages	LA= Local Authorities	FN= First Nation
APLM= Municipal Alliance	GoA= Government of Alberta	O= Operators (farm, golf course, etc.)
PLWA= Watershed Assoc.	NGO= Non-Governmental Organization	LA= Local Authorities

Note: Mun: the authority remains with each Municipality to separately act on a given recommendation. APLM (Alliance of Pigeon Lake Municipalities) provides a forum for municipalities to discuss practices and may recommend consideration by member councils, but final authority remains with the member councils

5) Time Frame: refers to time for substantial completion of recommendation. Lead time is often needed for movement on a given recommendation. Early actions are identified under Annual Priorities
6) Success Measure: Measures have been chosen based on the ability to measure outcomes.
7) Annual Priorities- 2018: An annual review of past progress and annual priorities would be conducted by The PLWMP Steering Committee.
8) LIVING PLAN & ANNUAL REVIEW: Lead agencies are requested to annually review recommendations under their purview, to determine and reassess priorities and report to the PLWMP Steering Committee.
9) PLWMP Steering Committee: this multi-stakeholder committee is the overall steward and coordinator of the PLWMP 2018. The Steering Committee needs to monitor progress and make course corrections as warranted, including reallocation of tasks and redefining time frames and success measures.

PLWMP 2018 OBJECTIVES

LAND COVER & BIODIVERSITY
OBJECTIVE 1: Increase land cover types (e.g. forest, wetlands) that have lower nutrient release rates, trap nutrients, and that promote biodiversity

LAND USE & PHOSPHORUS MANAGEMENT
OBJECTIVE 2: Improve phosphorus management for all land use activities to achieve a net reduction in nutrient runoff and promote biodiversity.

CLEAN RUNOFF
OBJECTIVE 3: Promote clean runoff practices to reduce the transport of nutrients to Pigeon Lake

GROUNDWATER QUALITY
OBJECTIVE 4: Protect groundwater that feeds into Pigeon Lake.

SHORELINES
OBJECTIVE 5: Improve the health and resilience of the shoreline and near-shore areas

PIGEON LAKE & IN-LAKE MANAGEMENT
OBJECTIVE 6: Improve knowledge about phosphorus and cyanobacteria dynamics affecting the lake to reduce phosphorus loading and the intensity of algae blooms.

OBJECTIVE 7: Investigate the feasibility and safety of in-lake options to reduce bloom formation and/or mitigate the effects of blooms and also to build local defences against harmful invasive species.

WORKING TOGETHER
OBJECTIVE 8: Improve regional collaboration, partnerships and organizational effectiveness to promote collective action for a healthy watershed, healthy lake and healthy community.

PLWMP 2018 Implementation Priorities

Arranged by: Recommendation Code

OBJECTIVE	Code	RECOMMENDATIONS	TYPE	ROLES	TIME FRAME	SUCCESS MEASURE
OB-1 Land Cover & Biodiversity	1a	Land Conservation: Conserve watershed priority areas with protective designations, including: the Provincial Park, private land conservation purchases, conservation easements, environmental reserves, and land use districts.	Policy	Lead: PLWMP Support: NGO, GoA, Mun, PLWA	00 Ongoing	Additional 10% over entire watershed

OBJECTIVE	Code	RECOMMENDATIONS	TYPE	ROLES	TIME FRAME	SUCCESS MEASURE
OB-1 Land Cover & Biodiversity	1b	Statutory Plans & Land Use Bylaws: Retain Natural Vegetation: Develop guidelines and implement policies and regulations within statutory planning documents and municipal land use bylaws to retain natural areas and wildlife corridor (e.g. 80% tree cover for 20-acre lots) within new subdivisions; and for the requirement for development permits for tree and natural vegetation removal on residential lots.	Policy	Lead: Mun Support: APLM, PLWMP	01 Short Term	100% municipal participation
OB-1 Land Cover & Biodiversity	1c	Statutory Plans & Land Use Bylaws: Wetlands: Implement policies and regulations in municipal planning documents to retain all wetlands and peatlands as nutrient traps. Implementation tools may include: · Requiring the delineation and classification of wetlands as a component of statutory plan development, subdivision or development permit applications. · Implementing development setbacks from wetlands and peatlands based on their classification	Policy	Lead: Mun Support: APLM, PLWMP	01 Short Term	100% municipal participation
OB-1 Land Cover & Biodiversity	1d	Restoration: Implement programs to encourage the restoration of natural vegetation on lands throughout the watershed including reforestation and restoration of wetlands using incentives such as the Alternative Land Use Services Program (alus.ca)	Community Action	Lead: PLWMP Support: Operators, Mun, GoA, PLWA, NGO	00 Ongoing	One project per year
OB-1 Land Cover & Biodiversity	1e	Mapping: map watershed priority areas such as wetlands, wildlife habitat, environmentally significant areas	Technical & Scientific	Lead: PLWMP Support: Mun, GoA, PLWMP	02 Medium Term	Task Completed
OB-2 Land Use & Phosphorous	2a-i	Statutory Plans & Land Use Bylaws: Lakeshore Environmental Area: Adopt an 800 metre "Lakeside Environmental Area" as per the Model Land Use Bylaw, that gives priority to land uses, policies, and environmental provisions designed to protect the lake from nutrient runoff. Policy provisions to include: · Requiring construction management plans with new development permit applications. · Restricting land uses within riparian areas that may increase runoff, increase the potential for contamination of groundwater, and/or impede the effectiveness of important recharge areas. · Restricting land uses within 800 metres of the lake where phosphorus and other nutrients, chemicals, or nutrient-rich sediment may pollute the waters of Pigeon Lake.	Policy	Lead: Mun Support: APLM, PLWMP, PLWA	01 Short Term	100% municipal participation

OBJECTIVE	Code	RECOMMENDATIONS	TYPE	ROLES	TIME FRAME	SUCCESS MEASURE
OB-2 Land Use & Phosphorous	2a-ii	. Requiring a development permit and providing guidelines for the stripping and grading of lands within 800 metres of the bank of Pigeon Lake. Where possible this activity should be discouraged and or sediment controls be implemented during and post construction to eliminate sediment loading of the lake during construction. · Requiring the application of local topsoil and native plants to be included in landscaping plans for new development and redevelopment areas. · Prescribing a maximum site coverage percentage for non-permeable surfaces on new development and re-development sites within 800 metres of Pigeon Lake. · Prescribing site coverage guidelines for natural vegetation cover that is compatible with FireSmart development principals. · Discouraging the compaction of soils during stripping and grading activities that may interfere with natural groundwater recharge and increase surface water runoff. · Prohibiting the excavation or filling in or clearing of all wetlands and stream courses and their associated riparian lands within 800 metres of the legal bank of Pigeon Lake.	Policy	Lead: Mun Support: APLM, PLWMP, PLWA	01 Short Term	100% municipal participation
OB-2 Land Use & Phosphorous	2b	Lawn Fertilizers and Pesticides: Continue to provide education and support for watershed residents to eliminate lawn fertilizers and pesticides on residential properties and to promote alternative practices.	Community Action	Lead: PLWA Support: Mun	05 Largely Completed	Annual Programs,
OB-2Land Use &Phosphorous	2d	Existing Agricultural Operations: Encourage agricultural operators to participate in whole farm reductions in phosphorus runoff using the Alberta Agriculture and Forestry Phosphorus Management Tool and the Environmental Farm Plan Program, and to adopt beneficial management practices that reduce nutrient runoff. Promote agricultural erosion and sediment control practices (e.g. low tillage).	Community Action	Lead: CountiesSupport: PLWA, PLWMP, APLM, GoA	00 Ongoing	Sector Participation
OB-2 Land Use & Phosphorous	2e	New or Expanded Intensive Livestock Operations: Statutory land use restrictions on new or expanded intensive livestock operations (including CFO's) are supported in this Watershed Management Plan	Policy	Lead: Mun Support: APLM, GoA, PLWA	00 Ongoing	No Intensive Livestock Operations

OBJECTIVE	Code	RECOMMENDATIONS	TYPE	ROLES	TIME FRAME	SUCCESS MEASURE
OB-2 Land Use & Phosphorous	2f	Recreational Operations: Encourage recreational land uses (e.g. golf courses, campgrounds) to adopt beneficial management practices (e.g. Audubon Certification) that reduce nutrient run off and promote biodiversity.	Community Action	Lead: PLWA Support: PLWMP, Mun, NGO, GOA	00 Ongoing	Sector Participation
OB-2 Land Use & Phosphorous	2g	Oil and Gas Operations: Encourage all oil and gas operations to adopt a best management practices on all well sites, batteries, and processing operations to reduce contaminants and phosphorous rich runoff. Encourage future operations to minimize land disturbances.	Community Action	Lead: PLWA Support: PLWMP, NGO, GOA	02 Medium to 03 Long Term	Sector Participation
OB-3 Clean Runoff	3a	Roads: Eliminate salt and pesticide applications for all road allowances within 800 metres of the lake.	Policy	Lead: Mun Support: APLM, PLWMP, PLWA	01 Short Term	100% Participation
OB-3 Clean Runoff	3b	Statutory Plans & Land Use Bylaws: New Subdivision Stormwater: Require all new developments to: · provide a storm water quality management plan that is net neutral or better in phosphorus release rates and incorporates low impact development drainage practices. · Regulating post development storm drainage flow to no net increase in amount or rate of water flow offsite. · When applicable, requiring developers to submit and follow Stormwater Site Implementation Plans (SSIPs) that comply with a Master Drainage Guidelines for the Watershed.	Policy	Lead: Mun Support: APLM, PLWMP, PLWA	01 Short Term	100% Participation
OB-3 Clean Runoff	3c	Statutory Plans & Land Use Bylaws: Sediment and Erosion Control: all new developments and redevelopment to institute a construction erosion and sediment control plan.	Policy	Lead: APLM Support: Mun, PLWMP, PLWA	01 Short Term	100% Participation
OB-3 Clean Runoff	3d	Beaver Management: Manage beaver populations and natural structures in tributaries to promote nutrient trapping while adequately protecting infrastructure and property.	Policy	Lead: PLWA Support: PLWMP, Mun, GOA	00 Ongoing	100% Participation
OB-3 Clean Runoff	3e	Clean Runoff: Promote clean runoff practices on private and public properties as per the Alberta Clean Runoff Action Guide.	Community Action	Lead: PLWA Support: Mun, NGO, GoA	00 Ongoing	Increased Participation

OBJECTIVE	Code	RECOMMENDATIONS	TYPE	ROLES	TIME FRAME	SUCCESS MEASURE
OB-3 Clean Runoff	3f	Water Quality Guideline: Develop a drainage water quality guide with quality and release rates guidelines for new major developments and proposed retrofits for existing drainage systems. Phosphorus is to be recognized as the water quality parameter of greatest concern for Pigeon Lake.	Technical & Scientific	Lead: PLWMP Support: APLM, Mun	02 Medium Term	Task Completion
OB-4 Ground Water	4a	Statutory Plans & Land Use Bylaws: Groundwater Conservation: Incorporate water conservation guidance tools into municipal statutory plans and development requirements.	Policy	Lead: Mun Support: APLM, PLWMP, PLWA	02 Medium Term	Task Completion
OB-4 Ground Water	4b	Statutory Plans & Land Use Bylaws: Groundwater Impact Assessments: Require new major developments in the watershed to demonstrate no negative impacts on existing groundwater users or the lake water supply.	Policy	Lead: MunSupport: APLM, PLWMP, PLWA	02 Medium Term	Task Completion
OB-4 Ground Water	4c	Wastewater Collection: Support the extension of a regional waste water system to lakeside communities including the two Pigeon Lake Provincial Park campsites.	Policy	Lead: Mun Support: APLM, PLWA, Local Authorities, GOA	02 Medium Term	Completion of system
OB-4 Ground Water	4d	Septic Fields: Eliminate septic fields for residential lots within the Lakeside Environmental Area	Policy	Lead: Mun Support: APLM, PLWA, Local Authorities, GOA	02 Medium Term	Elimination of remaining fields
OB-4 Ground Water	4e	Wastewater System Inspections: Promote regular inspections of both private and communal wastewater systems for integrity and leakage. Systems that fail are to be reported and repaired.	Policy	Lead: Mun Support: APLM, Local Authorities	00 Ongoing	100% Participation
OB-4 Ground Water	4f	Water Wells: Encourage home owners to adopt water conservation and well maintenance practices (e.g. GoA Working Well program)	Community Action	Lead: PLWA Support: Mun, NGO, GOA	00 Ongoing	Consistent Program
OB-4 Ground Water	4g	Industrial Groundwater Extraction: Monitor permit applications and Intervene where warranted on behalf of the watershed to maintain groundwater flows to the lake.	Community Action	Lead: PLWA Support: Mun, NGO,	00 Ongoing	Effective Monitoring

OBJECTIVE	Code	RECOMMENDATIONS	TYPE	ROLES	TIME FRAME	SUCCESS MEASURE
OB-5 Shorelines	5a	Statutory Plans & Land Use Bylaws: Shoreline and Tributary Setbacks: · For Sensitive shore lands: implement restrictive land use designations that preserve natural buffers · For new subdivisions: implement development setbacks from the surveyed shoreline of the Lake for new development, based on riparian setback guidelines with a minimum of 30 m, including restrictions for tree and vegetation clearing. At time of subdivision, where existing development would not make the provision of an environmental reserve inappropriate, require the provision of a 30-metre-wide environmental reserve adjacent to the shoreline of the lake. · For existing lot redevelopment: establish a minimum building setback as per guidelines set out in the Model Land Use Bylaw.	Policy	Lead: Mun Support: APLM, PLWMP, PLWA	01 Short Term	Task Completed 100% municipal participation
OB-5 Shorelines	5b	Statutory Plans & Land Use Bylaws: Shoreline Modification: Require bylaw provisions consistently across the watershed that any shoreline modification requires a development permit for lands above and abutting the legal bank. Municipal policies need to ensure that above legal bank modification approvals are conditional to a Provincial permit being in place for related modifications to the shore below the legal bank. Except for reasonable access shore lines are to be kept in a natural state. Modifications include regrading, natural vegetation clearing, drainage modifications.	Policy	Lead: Mun Support: APLM, PLWMP, PLWA	00 Ongoing	No shoreline modifications without approvals
OB-5 Shorelines	5c	Restoration of Aquatic Vegetation: Retain and re-establish cattail and reed beds to support fish habitat, provide erosion protection and filter nutrients.	Policy	Lead: GoA Support: Mun PLWA	00 Ongoing	Increased compliance
OB-5 Shorelines	5d	Lake Shoreline Property Management Guidelines: Develop a checklist and reference guide to assist development officers and lot owners in addressing the special development requirements for shore line lots. (e.g. On the Living Edge Update)	Community Action	Lead: PLWMP Support: PLWA, APLM, Mun	01 Short Term	Task Completion
OB-5 Shorelines	5e	Shoreline Practices and Restoration: Provide guidance documents, incentive programs, technical information, and support to shoreline landowners to implement healthy shoreline practices, shoreline restoration, and lake-friendly landscaping.	Community Action	Lead: PLWA Support: Mun, NGO, GOA	01 Short Term	50% Participation

OBJECTIVE	Code	RECOMMENDATIONS	TYPE	ROLES	TIME FRAME	SUCCESS MEASURE
OB-5Shorelines	5f	Algal Biomass: Provide guidance and support for landowners on addressing algal biomass accumulation along shorelines.	Community Action	Lead: MUN / PLWMP, Support: APLM GoA	00 Ongoing	Consistent information
OB-5 Shorelines	5g	Noxious Weeds: Continue invasive species eradication programs, including education, monitoring, and eradication of prohibited noxious weeds.	Community Action	Lead: MUN + PLWA Support: NGO	00 Ongoing	Outbreaks under control
OB-5 Shorelines	5h	Shoreline Health Assessment: update the Pigeon Lake shoreline and tributary shoreline health (riparian) assessment	Technical & Scientific	Lead: PLWMP Support: PLWA GOA	01 Short Term	Task Completion
OB-5 Shorelines	5i	Mapping: Undertake a comprehensive inventory of critical fish and wildlife habitat (such as Sensitive Habitat Inventory Mapping)	Technical & Scientific	Lead: PLWMP Support: PLWA	02 Medium Term	Task Completion
OB-6 Improve Knowledge	6a	Advancement of Science: Identify knowledge gaps relating to the formation of cyanobacteria blooms and techniques for meaningful reductions. Prioritize specific investigations and research projects. Source funds and implement ongoing research for Pigeon Lake.	Technical & Scientific	Lead: PLWMP Support: APLM, Technical Specialists, PLWA, GoA	00 Ongoing	Coordinated Published program.
OB-7 Invasive Species	7a	Invasive Species: Complement the Government of Alberta's province-wide efforts with local initiatives to improve education and build local defenses to keep out aquatic invasive species. Measures include monitoring, public education, signage, and other initiatives	Community Action	Lead: PLWA Support: APLM, Mun, Technical Specialists, PLWMP, GoA	00 Ongoing	Effective local program
OB-7 In-Lake Management	7b	In-Lake Management: Evaluate potential management options including project description, costs and financing; effectiveness in reducing phosphorus and algal blooms; reapplication frequency; environmental, social, and economic risks; and regulatory concerns. Implement where feasible.	Technical & Scientific	Lead: Mun Support: APLM, Technical Specialists	00 Ongoing	Coordinated published program.
OB-8 Working Together	8a	Statutory Regional Plans: Work toward a watershed-wide Intermunicipal Development Plan (IDP), Regional Collaboration Framework and a sub-regional plan under the North Saskatchewan Regional Plan that all align with the Pigeon Lake Watershed Management Plan. Measures of the Pigeon Lake Watershed Plan 2000 not addressed in the 2018 version will remain in effect until addressed in statutory Plan updates.	Policy	Lead: Mun Support: APLM, PLWMP, PLWA, GoA	01 Short Term	Task Completion

OBJECTIVE	Code	RECOMMENDATIONS	TYPE	ROLES	TIME FRAME	SUCCESS MEASURE
OB-8 Working Together	8b	Municipal Development Plans: Work toward consistent municipal development plans for all Summer Villages, that incorporate the environmental protection policies of the Watershed Management Plan and the Model Land Use Bylaw	Policy	Lead: Mun/APLM Support: PLWMP, PLWA, GoA, TS	01 Short Term	Task Completion
OB-8 Working Together	8c	First Nations: Engage the First Nations of IR 138A Pigeon Lake Reserve in the Watershed Management Plan.	Policy	Lead: PLWMP/ First Nations Support: APLM, PLWA, GoA	01 Short Term, to Ongoing	Ongoing
OB-8 Working Together	8d	Watershed Management Plan Updates: Revisit and update the Watershed Management Plan every five years and rewrite the Plan every ten years to accommodate the changing condition of the lake, success of current recommendations, new scientific knowledge, new legislation, and new stakeholder and organizational assets and interests.	Policy	Lead: PLWMP Support: APLM, PLWA, GoA	02 Medium to Long Term	Task Completion
OB-8 Working Together	8e	Assess Organizational Assets: Investigate organizational options to increase effectiveness, staff resources, financing, risk management, and accountability in undertaking watershed and lake management tasks, including coordination of scientific inquiry, action by municipalities, and community action.	Policy	Lead: PLWMP Support: APLM. PLWA, GoA	Short to 02 Medium Term	Task Completion
OB-8 Working Together	8f	Incentives to Promote Voluntary Action: Develop non-monetary and monetary incentive programs to promote voluntary action for individuals, municipalities and organizations	Community Action	Lead: PLWA Support: PLWMP, APLM, GoA, NGO	00 Ongoing	Program of Incentives
OB-8WorkingTogether	8g	Communication and Engagement Plan: Establish a communications and engagement plans for disseminating and reporting Plan progress to and amongst stakeholders.	Community Action	Lead: PLWASupport: PLWMP, APLM, PLWA, GoA	01 Short Term, Ongoing	Consistent Program
OB-8 Working Together	8h	Monitoring Plan: Develop a monitoring plan for environmental trends including lake and tributary water quality and for plan performance including fulfillment of success measures.	Technical & Scientific	Lead: PLWMP Support: PLWA APLM GoA	02 Medium Term, Ongoing	Effective Monitoring Program
OB-8 Working Together	8i	Phosphorous Budget: Continue to update and refine the phosphorus budget.	Technical & Scientific	Lead: GoA Support: PLWA PLMMP, APLM	02 Medium Term	Task Completion

APPENDIX B: COMMUNITY ENGAGEMENT

Background

The Pigeon Lake Watershed Association was formed in 2007 in response to a need for organized and science-based actions to be taken by the watershed residents to address ongoing concerns of diminishing water quality. In 2008, a State of the Watershed report was completed. Included was a recommendation for the preparation of a watershed management plan, which inspired the PLWA to begin work on the plan. This initiative took several years to get started, and to achieve support from the PLWA Board, the Pigeon Lake Municipalities and to build the necessary leadership resources.

In 2012 a Steering Committee was formed to undertake the preparation of the Pigeon Lake Watershed Management Plan. This initiative was funded by the PLWA and supported by the Battle River Watershed Alliance (BRWA), Alberta Environment, and various individuals and municipalities from around the lake.

Further support for the preparation of the Plan was obtained when the Alliance of Pigeon Lake Municipalities (APLM) made a commitment to the preparation of the plan and provided members to sit on the Pigeon Lake Watershed Management Plan (PLWMP) Steering Committee.

It was recognized that a multi-pronged watershed, in-lake and united approach was needed to achieve meaningful action. This was later confirmed by a PLWA membership poll (See *Synopsis of Responses on the PLWA Summary Report on the Methods for the Control of Nuisance Blue-Green Algae (Cyanobacteria),* January 2013). The APLM and the PLWA agreed that a cooperative approach was needed to undertake the important tasks identified for this project. This included increased communication between the two organizations and with the watershed residents. It was recognized that the lake needed more leaders to be involved and to work together in a meaningful way. On April 28th, 2012, the first meeting of Pigeon Lake leaders, the "Gathering for the Health of Pigeon Lake", was held with representation by many municipal councillors and members from two of the First Nations bands, including one Chief and an Elder. This meeting provided focus for the planning process. Based on the success of this meeting, it continued on an annual basis as the Annual Leaders Session.

The work on the plan moved forward by expanding the Steering Committee membership to include local organizations and our Healthy-Lake Partners, (i.e. non-governmental organizations such as the Battle River Watershed Association, and the Alberta Lake Management Society.

Recognizing the importance of engagement, the Steering Committee formed an Engagement Sub-Committee to create a PLWMP Engagement Strategy to ensure that engagement would be an integral part of all the PLWMP work.

During the 2013/14 timeframe, a Terms of Reference for the Plan was developed. The work of the PLWMP was defined in the Terms of Reference as a series of topics leading to the creation of Beneficial Management Practices. Topics were to be addressed over a number of years. Each topic was to have its own terms of reference, committee structure and an engagement component to help build consensus around each new topic. Engagement activities leading to the approval of the Terms of Reference included:

- ✓ Public on line survey entitled "Are we on Track?"
- ✓ Creation of a PLWMP website (www.plwmp.ca)
- ✓ Advertised public workshops
- ✓ 2013 Leaders Session and workshop
- ✓ 2013 PLWA AGM presentations
- ✓ Representations to federal and provincial elected officials and Cabinet ministers.

The 2013 Leaders Session supported topic priorities and also highlighted the need for Government of Alberta support and involvement in the Plan.

A new PLWMP website (www.plwmp.ca) was launched to ensure that the initiative would stand alone and be seen as everyone's plan. Other methods of communication for the PLWMP include PLWA emails and survey invitations, updates on municipal websites, joint APLM/PLWA newsletters, print media advertising for events and PLWA displays at local markets. The PLWA continues to fund and resource much of the engagement and communications. The PLWA contact list includes PLWA members plus key municipal, provincial, federal and Muskwacis Cree contacts. Engagement with the Muskwacis Cree run PL Reserve 138A is a priority, including participation in the Annual Leaders Sessions.

In 2013, three PLWMP open houses and presentations were marketed by various media methods and held on different sides of the lake.

In August of 2013, a survey of 618 community members was conducted and a local paper ad invited other watershed residents to participate. The survey "PLWMP – Are We On Track?" received 184 responses on behalf of at least 386 people. Over 95% of the survey respondents were either fully or somewhat supportive of the goal, guiding principles, PLWMP process and need to create a watershed plan for Pigeon Lake. A sense of urgency and concern for the degradation of the water quality and natural habitat permeated many responses. These responses gave a clear endorsement for the direction and focus of the PLWMP being taken by the Steering Committee.

The Steering Committee moved forward on the highest priority topics. Two topics were chosen as a starting point: Soil Management and Cosmetic Fertilizers, and the Model Land Use Bylaw.

A "Cosmetic Fertilizers: What do you think? Survey was conducted". This time, 344 surveys were completed on behalf of at least 745 people. The responses called for an immediate call for action which led to the municipalities writing bylaws prohibiting lawn fertilizers and, in some cases, lawn herbicides. In addition, the Healthy Lake Lawn campaign was born. Reports on the surveys are created and made available to the public via the PLWA websites.

Starting in 2014, the PLWA has hired summer staff to increase our outreach, disseminate information and receive the views of those in the watershed.

In 2015, a three-year Healthy Lake Clean Runoff Project was initiated given responses to a survey that told us: "We will make changes if you; "Tell us what to do", "Tell us how to do it", and "Make it easy". We focused on actions to clean the runoff from the near shore communities. It involved the creation of the Alberta Clean Runoff Action Guide to tell what and how, demonstration sites, a rain barrel campaign, many communications such as local press articles, and bringing resources to events such as native plants and grass seed; and a video to encourage residents to "Be Part of the Solution and to add some of the clean runoff approaches on their lot.

336 responses on behalf of at least 751 people to an end of project survey informed us that people were reading the CR Action Guide; were talking with neighbours about the need to make changes; that at least 350 changes had been made; and that another 375 were planned.

Each year, updates and progress made on the PLWMP is communicated through various means:

- ✓ Newsletters – spring and fall since 2007, and joint APLM/APLM since 2016
- ✓ Summer Students - since 2014
- ✓ Local Notice Boards
- ✓ PLWA AGM Presentations and Open House
- ✓ PLWMP and PLWA websites
- ✓ Annual Pigeon Lake Leaders Session
- ✓ Facebook (Pigeonlakewatershedassociation) since 2014
- ✓ Pigeon Lake Twitter

Pigeon Lake Watershed Management Plan 2017

In 2016, the Steering Committee initiated the writing of a Pigeon Lake watershed management plan for Pigeon Lake that addressed a complete range of topics related to: the watershed, the shore, the lake and working together. Support for this initiative came from the Government of Alberta, the Board of the PLWA and the Alliance of Pigeon Lake Municipalities plus our Healthy Lake Partners. Engagement strategies and techniques for PLWMP 2017 were adapted from earlier work of the Steering Committee.

The PLWMP engagement continued throughout 2017 in stages including:

- **Preparation of the Science Summary and Initial Drafts:** A day-long meeting was held in January of 2017 at the University of Alberta, organized by the PLWMP Chair. Attendees were a mix of researchers from the University of Alberta, Alberta Health, Consultants including Aquality Consultants Ltd., CPP Environmental, Hutcheson Environmental, Alberta Lake Management Society, Government of Alberta and members of Pigeon Lake organizations including PLWMP Steering Committee, the PLWA, and the APLM including their In-Lake Technical Committee. The objective was to identify the state of knowledge for Pigeon Lake, current initiatives, and critical information gaps. This information provided background to the introductory material in each section of the main report and to the technical summary in this appendix.

Leader's Session Draft – April 2017

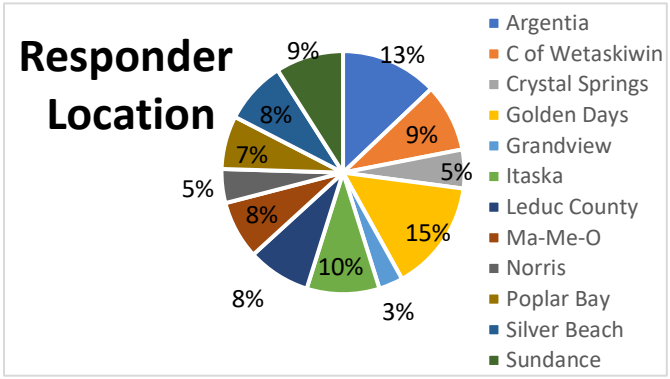
- April 2017, Leader's Session Draft of the Plan: This draft was prepared and issued to the 2017 attendees of the Annual Leader's Session. Forty-eight Pigeon Lake leaders participated including councillors, First Nations, PLWA directors, lake experts and planners. The draft Plan was discussed, and input gathered to improve it. An online survey was completed by 15 participants. This feedback resulted in revisions and updates for the next version.

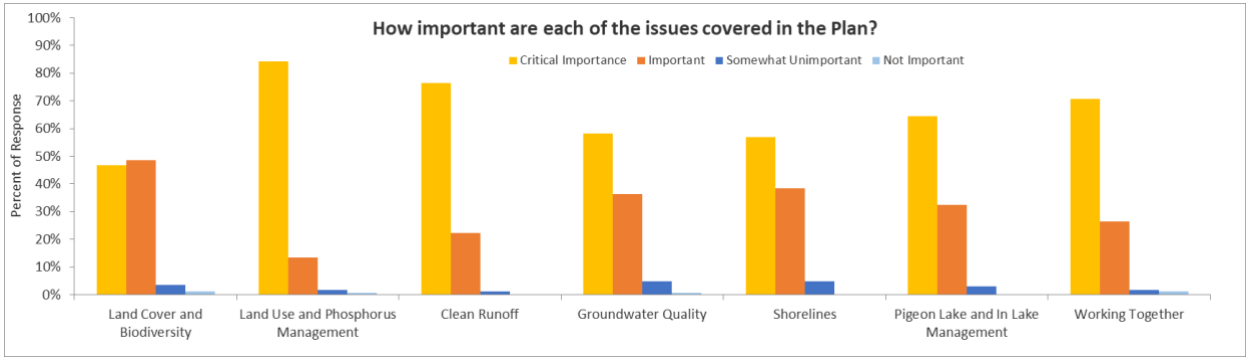
- June 2017, Public Draft of the Plan - Open Houses: the public draft was posted to the PLWMP website and invitations were issued to attend two public workshops and to complete and online survey. Sixty-five people attended the two PLWMP Open Houses. These were advertised in local newspapers, local websites, PLWA emails, Facebook, Twitter and a County of Wetaskiwin 'news flash.'

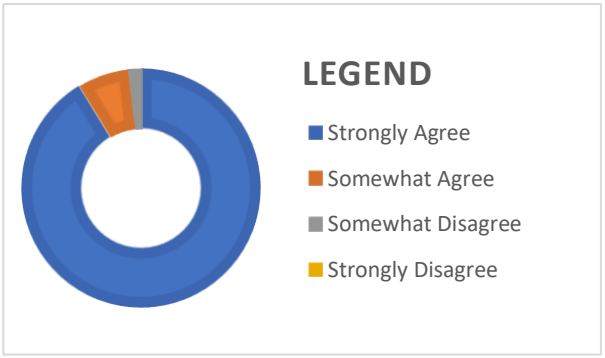
- June- September 2017, Various Events - The PLWA highlighted the Plan at:
    - Summer Village Annual Information Meetings
    - PLWA Annual General Meeting
    - Several Farmer's markets

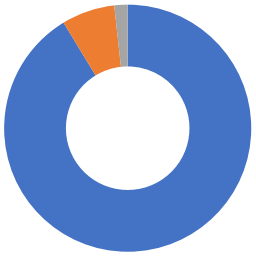
  Panels about the Plan were displayed to encourage discussions and people were asked to read it and complete the on-line survey.

- June 2017, Public Draft of the Plan- On Line Survey: An on-line survey ran over the summer. This was advertised by emails, Facebook posts, and a local paper article (Pipestone Flyer July 12, 2017). A total of 176 people filled in the survey on behalf of at least 397 people of which 95.5% own property around Pigeon Lake. Strong support was indicated for the Plan (see graphs next page)

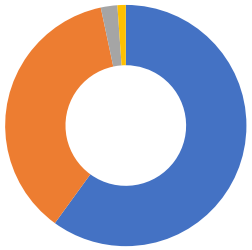




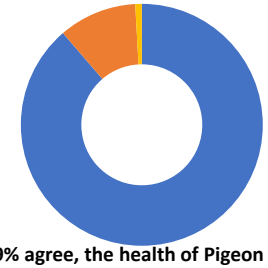




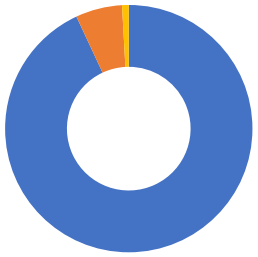
91% Agree with the Plan Vision



95% agree or somwhat agree, The Plan can be implemented.



89% agree, the health of Pigeon Lake requires urgent, decisive, and collective actions across all sectors.



93% agree, Improve the health of the watershed & the lake.

Adoption Draft – September 2017 – June 2018

In September 2017, the Plan was revised based on the public feedback and published to the PLWMP web site as the "adoption draft". A summary of the response to the online public survey was also posted to the site. This version of the Plan was then taken to all municipalities, Healthy Lake Partners and the Maskwacis Cree and the Government of Alberta for statements of adoption, endorsement or support. Organizations were invited to review the document and provide comment and or statements of support. A number of comments and concerns were addressed throughout this process that resulted in changes to the recommendations or text of the final PLWMP document.

- **September 20,** 2017, the Alliance of Pigeon Lake Municipalities voted to endorse the PLWMP.
- **September 09, 2017 –** the PLWA Executive Director gave an update to the Pigeon Lake Regional Chamber of Commerce board. They were asked to consider endorsing the PLWMP. The PLWA is a member of the PLRCC and the PLRCC participates in the annual Leaders Session and sits on the PLWMP Steering Committee.
- **September 29, 2017 –**, PLWMP Chair presented the PLWMP at the Annual Conference of the Alberta Lake Management Society
- **December 4,2017** the Pigeon Lake Watershed Association voted to endorse the PLWMP.
- **September 2017– May 2018 On-going –** The PLWMP Chair and Vice Chair presented the PLWMP to all watershed municipalities and organizations who have sat on the Steering Committee, with the intention of firstly obtaining comments and secondly to obtain resolutions in support of the plan.

Maskwacis Cree and the Pigeon Lake Reserve Engagement. Since the PLWA began, engagement with our First Nation neighbours has been important. In 2017, the PLWMP adoption draft gave further impetus for working together. Examples of past engagement of First Nations include:

- **Annual Leaders Sessions:** All four nations have always been invited, and we usually have a handful attend including Chiefs, Councillors and Elders.
- **PLWA Events:** On occasion First Nations have attended our workshops and Annual General Meetings including a few people from the PL Reserve.
- **POW WOW's:** On occasion the PLWA has attended the local Pow Wow and the 2015 PLWA President was honoured to be invited in the Samson Cree Nation POW WOW and participate in the Grand Entrance

- **PLWA Representations at First Nations Organized Events:** the PLWA has made a handful of presentations to different First Nations groups: A TSAG arranged meeting with Elders and a Technical Committee who were working with Imperial Oil to address the abandoned wells on the reserve.

- **First Nation Representation on the PLWA Board**: Chief Leonard Standing-On-The-Road (Elected Chief of the Montana Nation in 2017) served on the PLWA Board from 2012 through 2015, as the PLWA First Nations Liaison. In 2017, past Erminskin First Nation Councillor, Samuel Minde began to sit on the PLWA Board as the First Nation Liaison. Samuel has worked to form the First Nation working group called: Mamawo Group (Together).

- Muskwacis Cree Mamamo Group (Together).

  In 2017, the PLWA Director and Muskwacis Cree Nations liaison took it upon himself to pull together a group representing all four Nations to see if there was any interest in getting involved with the PLWA and work going on around the lake. At an initial meeting a lot of concern for the lake and how its health impacts people living on the Reserve; the fishery and more was expressed. A series of meetings which also included the GoA, the BRWA, and three PLWA Directors. Four of these people were also members of the PLWMP Committee including the Chair and all were members of the Engagement Sub-committee.

  The outcome of the initial meetings were two documents to be presented to the Maskwacis Cree Council of Chiefs and Councillors for endorsement. One is a Letter of Support for the PLWMP and the second a Terms of Reference for the Mamawo Working Group to:

  - Explore how the PLWMP may be important for the Pigeon Lake Reserve.
  - Build bridges with the PLWMP steering committee and have a voice in the work being done.
  - Provide the Maskwacis Cree Nations and the Pigeon Lake Reserve Residents with opportunities to be informed and to participate in the implementation of the PLWMP.
  - Identify and share the tools and knowledge from this work, for the benefit of the Maskwacis Cree Nations.

APPENDIX C: TECHNICAL SUMMARY

PREFACE

The Technical Summary has been assembled as a foundation to the development of the Pigeon Lake Watershed Management Plan 2017 ("the Plan"). It is intended to update information found in the 2006 State of The Watershed Report and to provide benchmark updates to many of the environmental indicators relevant to Pigeon Lake and its watershed. General watershed planning implications are also identified related to the various topics. These have generally been the background to many of the specific recommendations in the Plan, that were then further refined to address planning policies and tools available.

This summary was prepared by Adam Kraft and Théo Charette from CPP Environmental, with hydrological contributions from Alberta Environment and Parks.

Pigeon Lake is a relatively well-studied lake; several studies have examined the complex interactions between watershed activities and the lake's ecological health. These studies have improved our understanding of Pigeon Lake and have indicated potential natural and human-caused drivers of the nuisance algal blooms (or Harmful Algal Blooms, HABs). The intent of this document is to summarize the current scientific knowledge around the water quality concerns of Pigeon Lake and to highlight where further research or remedial efforts are needed.

The document is organized into three main sections, which outline the state of knowledge at different spatial scales: (i) the Pigeon Lake watershed (Section 1: "Watershed Lands"), (ii) the lake's streams and shorelines (Section 2 "The Shoreline"), and (iii) Pigeon Lake itself (Section 3:"Pigeon Lake").

1 SUMMARY OF THE SCIENCE: WATERSHED LANDS

Nutrient Production and Transport

Surface water flows (overland runoff and streams) make up an estimated 29% of Pigeon Lake's water inputs (Worley Parsons 2010) and transport nearly half of the externally-loaded phosphorus (P, an important nutrient for biological growth) into the waterbody (FIGURE C1). This indicates that both the water quantity and quality of the lake are influenced by the land cover composition of the watershed. The amount of forest and wetland cover is important for aquatic health, yet only 39% of ecological lands remain in the Pigeon Lake watershed. Human activity is extensive, with 61% of the land converted into agricultural or built-up areas (e.g., roads, residential, recreation areas) as of 2013 (FIGURES C2, C3).

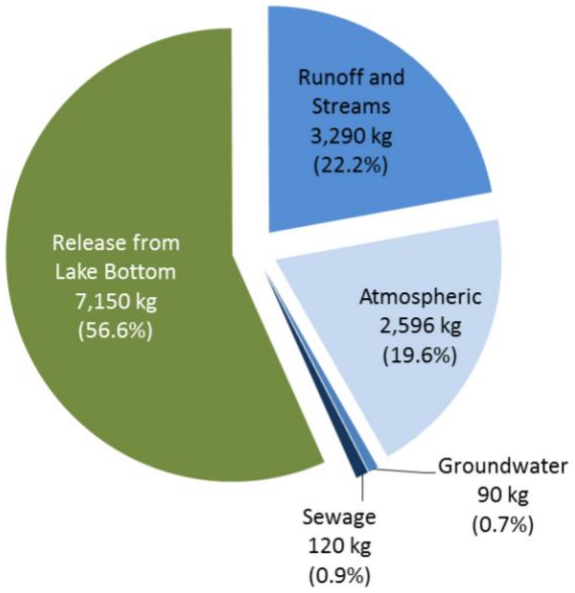


Figure C1: Annual open water season total phosphorus loadings, both bioavailable and particulate forms, into Pigeon Lake in 2013, indicating the relative partitioning between internal and external loadings (Teichreb 2014). Internal loadings refer to the release of P from the lake bottom sediments, whereas external loadings include the runoff from the watershed (i.e., measured flow from streams and creeks that enter the lake and unmeasured diffuse runoff), as well as atmospheric deposition, groundwater inputs and sewage. It is important to note that these results come from one year (2013) of stream sampling data, and thus do not represent average or typical conditions.

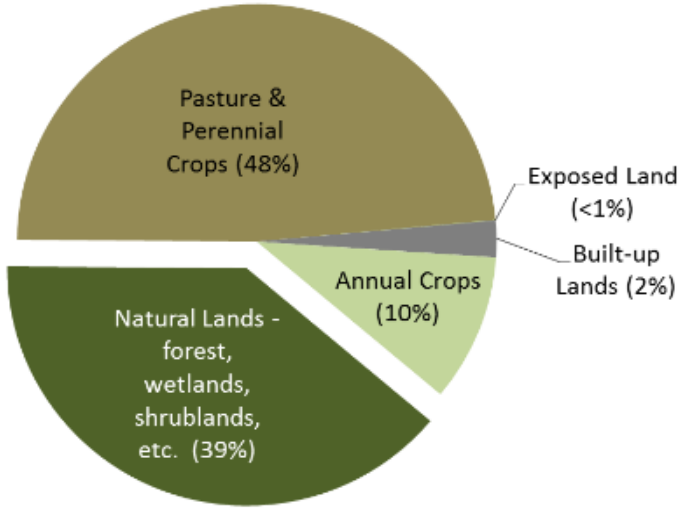


Figure C2: Landscape composition of the Pigeon Lake watershed based on 2013 conditions, showing the relative cover of natural and non-natural land cover types (AAFC 2013).

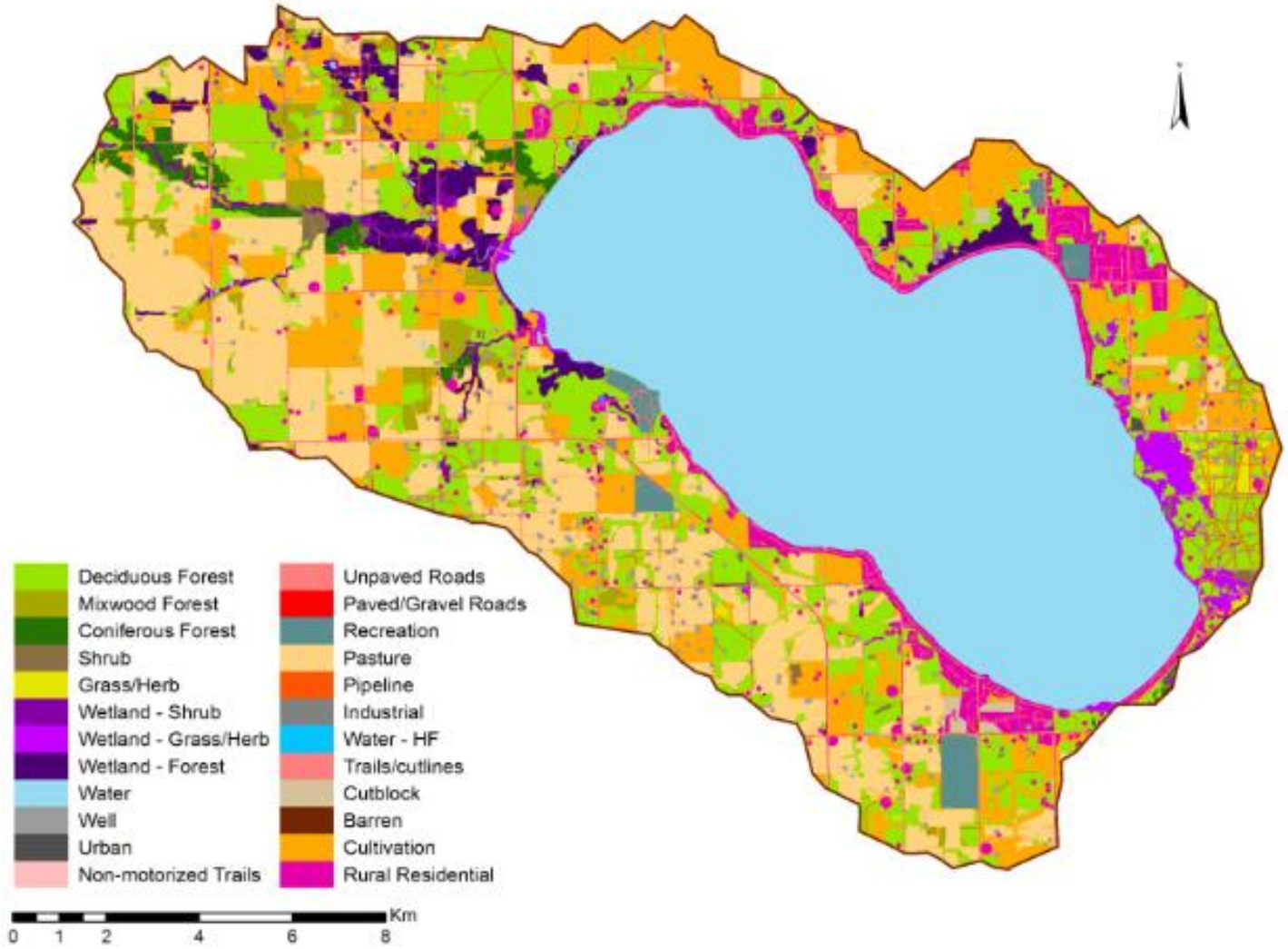


Figure C3: Landscape composition of the Pigeon Lake watershed based on 2012 conditions (Habib 2017).

Runoff from developed areas occurs mainly during spring snowmelt and following rainfall events, and can contain large quantities of nutrients from fertilizers, manure, decayed plant material, and loosened soil particles which will ultimately enter Pigeon Lake. Unlike point source pollution from industrial sites or sewage treatment plants (where the source of pollution is easily identified), sources of pollution resulting from runoff, precipitation or atmospheric deposition are difficult to identify and control due to the multiple sources of pollution and the large transport capacity. These sources of pollution are called non-point (or diffuse) and are mainly influenced by the type of land cover (e.g., agricultural activities, urban areas or natural vegetation cover) and the human activities in the watershed (e.g., pesticides and nutrients from lawns and gardens, land clearing and disruption of the riparian area).

The Pigeon Lake watershed contains considerable rural development and seasonal activity, with extensive cottage and municipal development along the lakeshore and over 100,000 seasonal visitors. While the direct impact of this population on lake water quality is challenging to quantify, a considerable proportion of the external nutrient loading into Pigeon Lake can be attributed to human presence. Human-generated land cover changes and use increase nutrient loading in two main ways:

1. Increasing the nutrient availability in the watershed:
    - Nutrient additions related to lawn fertilizers and agricultural operations.
    - Release of some proportion of sewage and pollutants produced from cottages, campgrounds and day-use areas
2. Facilitating the introduction of nutrients into the lake:
    - Removing natural vegetation and riparian buffers, which act as filters for nutrients and other pollutants
    - Increasing the percentage of hard surfaces, which decreases infiltration, increases the overland flow, and entrains pollutants
    - Land disturbances that release sediment containing phosphorus

Nutrients – notably phosphorus (P) and nitrogen (N) – enter Pigeon Lake directly through seven inflowing streams and many drainage ditches. Nutrient loading rates (annual export quantity; FIGURE C4) varied among streams and with the stream's discharge rate (FIGURE C5). Peaks for P- and N-loading in streams typically occurred in April, decreased through May-June, increased again in July-August (due to storm events) and continued to decline into September-October. 2013 data showed that the streams contributed a relatively small proportion of total external nutrient inputs into Pigeon Lake (collectively, approximately 377 kg/year, or about 11% of total external loadings). However, this information should be used with caution since the 2013 sampling missed a portion of spring runoff as sampling began on April 25th of that year. Generally, comprehensive annual water quality data for the inflowing streams are largely lacking relative to data records for the lake itself.

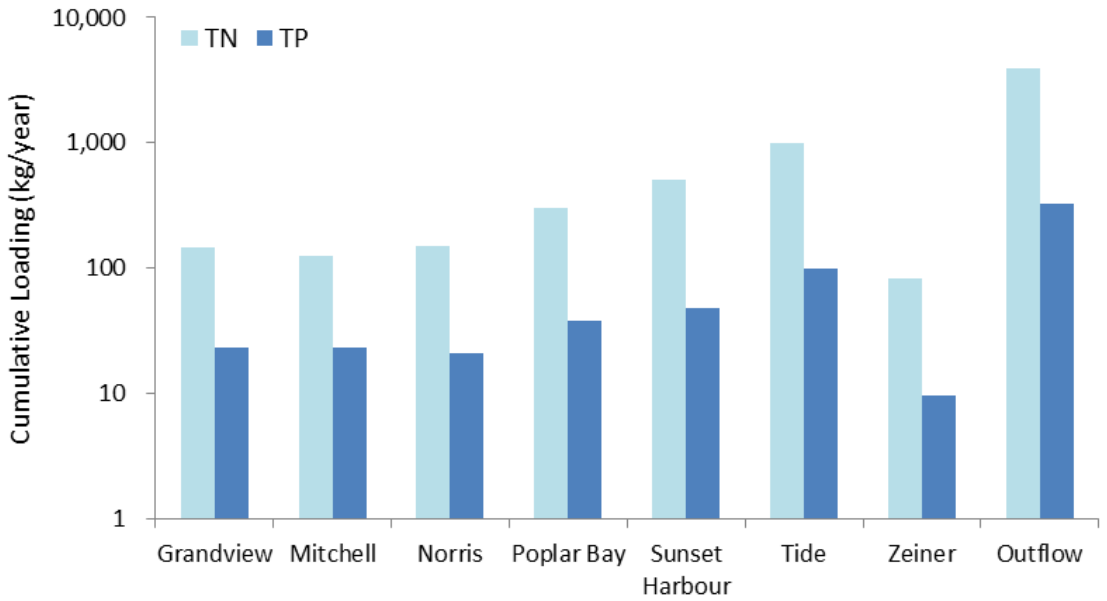


Figure C4: Summary of cumulative annual total nitrogen (TN) and phosphorus (TP) loading from inflowing streams into Pigeon Lake and exports from the outflowing stream in 2013. Data are from Teichreb et al. 2014.

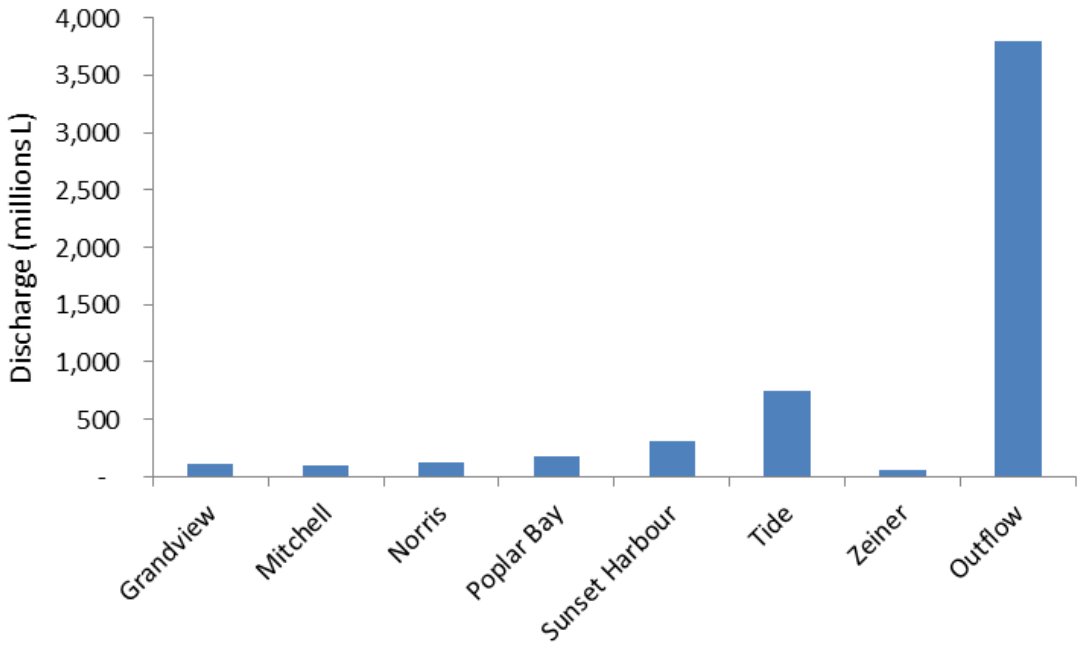


Figure C5: Summary of cumulative annual discharge from inflowing streams into Pigeon Lake and export from the outflowing stream in 2013. Data are from Teichreb et al. 2014.

Land disturbance and development within the watershed contribute to soil erosion and accelerate the rate of nutrient transport to the lake. In particular, the clearing of forests greatly increases the rate of snow melt and thus runoff from the land. Historically, riparian vegetation immediately adjacent to the banks of Pigeon Lake and its inflowing streams are thought to naturally mitigate the rates at which runoff-borne nutrients directly enter the water. Ongoing development has led to the degradation and destruction of these natural buffers, resulting in minimal filtration (i.e. removal of excess nutrients) before they reach the water. Increased land disturbance and the loss of riparian areas increase the rates at which both diffuse and point-source nutrient inputs enter Pigeon Lake. This has other consequences for water quality such as an increase in suspended materials due to increased shoreline erosion.

Phosphorus Forms, Cycle and Sources

In most temperate lakes the nutrient that is in shortest supply, and is therefore limiting to biological productivity, is P. Once P exists in sufficient quantities, growth of phytoplankton can proceed until limited by another factor (e.g., light, nitrogen (N) or wind). Excessive quantities of P can promote problematic overgrowth of cyanobacteria, also known as blue-green algae blooms. Cyanobacteria blooms can sometimes produce dangerous toxins, negatively impacting water quality and causing problems for human and ecological health. While many central Alberta lakes, including Pigeon Lake, are naturally productive, increased human development and land cover changes within watersheds over the past century appear to have increased the rates of P input into waterbodies and accelerated eutrophication rates. Thus, quantifying P inputs into waterbodies is an important first step towards controlling eutrophication to help prevent future water quality issues.

Phosphorus compounds enter the lake in different forms and compositions, depending on their origin. Once in a water body, P undergoes complex chemical and biological reactions which result in it entering the water column. There are two main forms of P: dissolved (soluble) and particulate (as a component of organic and particulate matter). The primary dissolved form of P (orthophosphate, or PO_4^{3-}) is readily available for phytoplankton and plant uptake. In response to varying environmental conditions, particulate P can change from one chemical form to another (a process known as P cycling). For example, microbial decomposition of organic matter can turn organic particulate P into its dissolved form, while in the mineral form, such as clay particles, the process is of a much longer term. Other chemical and physical changes in the water column and the lake sediments can also convert P in soil mineral particles to dissolved P.

FIGURE C6 shows a simplified P cycle in lakes. Phytoplankton and bacteria assimilate dissolved inorganic P and transform P into particulate organic P as it becomes part of their tissues. As plants and animals excrete waste or die, the organic P sinks to the bottom, where bacterial decomposition turns it back to inorganic P. This inorganic P ultimately returns to the water column and becomes again available for uptake. In the sediment, inorganic P will not pass freely into the water column if the sediment-water interface is well oxygenated. In this situation, P is bound to clays and different compounds, such as iron (Fe), calcium (Ca) or aluminium (Al). In some circumstances, increased P release in well oxygenated sediment has been observed at high pH values following resuspension events in the summer when pH increases due to the high photosynthetic activity. However, anoxic (non-oxygenated) sediments release phosphate to the overlying waters at a much faster rate.

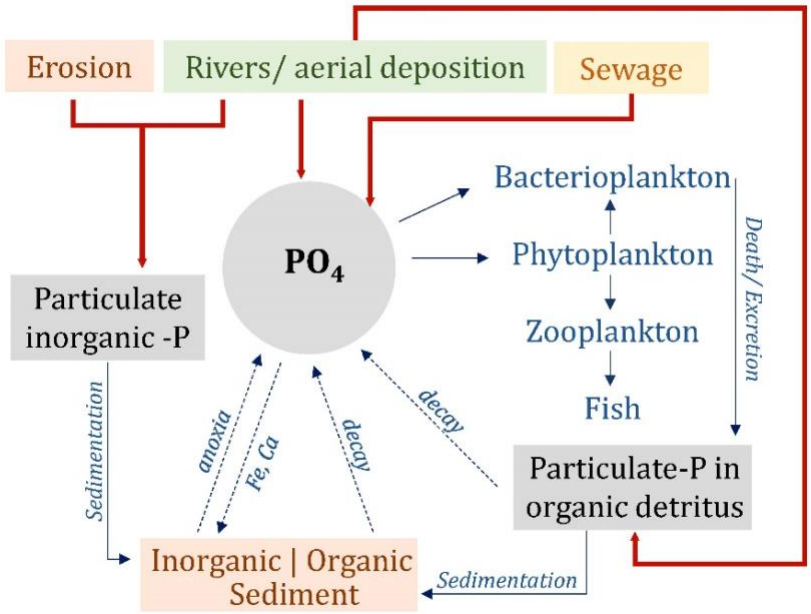


Figure C6: A simplified P cycles in lakes. Red lines = external loading. Dotted blue lines = internal loading. Solid blue lines = internal recycling.

Due to the changes in P forms, the term Total Phosphorus (TP) is used to determine the total amount of P present in the water body, regardless of its chemical identity (dissolved and particulate). However, this term does not inform about the availability of P for plant or phytoplankton uptake – a concept named "bioavailability". The relative proportion of dissolved vs particulate P that enters to a water body will therefore influence algal growth. Particulate forms of P typically enter the lake via wind transport, atmospheric deposition or through erosive processes and subsequent sediment transport. Orthophosphate (i.e., dissolved) forms are generally produced by natural processes. Point sources (e.g. effluents from treatment plants or untreated water), and nonpoint or diffuse sources (e.g. runoff from agricultural sites and application of some lawn fertilizers) largely contribute to the input of dissolved P forms.

In 2014, the Government of Alberta developed a P budget for Pigeon Lake to quantify the total P inputs into and outputs from the lake (Teichreb 2014). The report included external and internal sources (i.e., P from the watershed or atmosphere, and P released from the lake sediments, respectively) and concluded that both contribute to elevated nutrient levels. Relative annual contributions of the total P inputs were estimated to be approximately 43% (5,755 kg/year) from external and 57% (7,510 kg/year) from internal sources (FIGURE C1). Most importantly, this report determined that there is no single problematic external source of P for Pigeon Lake. Of the P that comes from external sources, it was estimated that approximately 48% (2,913 kg/year) comes from diffuse runoff, 43% (2,596 kg/year) comes from dustfall and precipitation, and 9% (587 kg/year) comes from groundwater, point-source inflows and sewage combined (FIGURE C1). Point-source and sewage contribution might seem proportionally small when compared to the contribution of other sources to the total amount of P entering the lake, yet most of the P supplied by these sources correspond to the more readily bioavailable fraction and as such are critically important. Additionally, the specific P contributions from each of these sources may vary among seasons and years according to factors such as wind and precipitation patterns or land use activities (e.g., whether a field is in fallow or being actively tilled and fertilized).

A recent report from the Alberta Biodiversity Monitoring Institute (ABMI; Habib, 2014) expanded upon the initial Pigeon Lake P budget work by using an updated and more-detailed land cover data set (FIGURE C3 and C7), as well as a range of future development scenarios based on the Leduc County's North Pigeon Lake Area Structure Plan (Leduc County 2011) and the County of Wetaskiwin Pigeon Lake Watershed Area Concept Plan (County of Wetaskiwin 2014). This study aimed at evaluating changes in P load into the lake under a variety of development scenarios (new rural and lakeshore development) and land management practices (reforestation and restoration of riparian buffers). However, this model only estimated stream and overland inflows into the lake, and did not consider other external sources (e.g., atmospheric or groundwater inputs) or internal sources (from the lake

sediments). The simulation for the current land scenario indicated that the annual point source and diffuse P loading was 3,707 Kg/year, about 12.6% larger than the input from surface runoff estimated in the original P budget (i.e., 3,290 Kg/y). Despite the differences, both estimates were in the same order of magnitude and discrepancies were likely the result of the inherent model structure and methods for the estimation of complex processes such as nutrient export or retention in a highly developed watershed. Thus, the *relative proportions of P contributions*, rather than the precise loading values, should be considered when determining how to control excess nutrient loading into Pigeon Lake.

Figure C7: Map of watershed-level phosphorus exports into Pigeon Lake, modelled according to current land use intensities. Inflowing and outflowing creeks are indicated (Habib 2017).

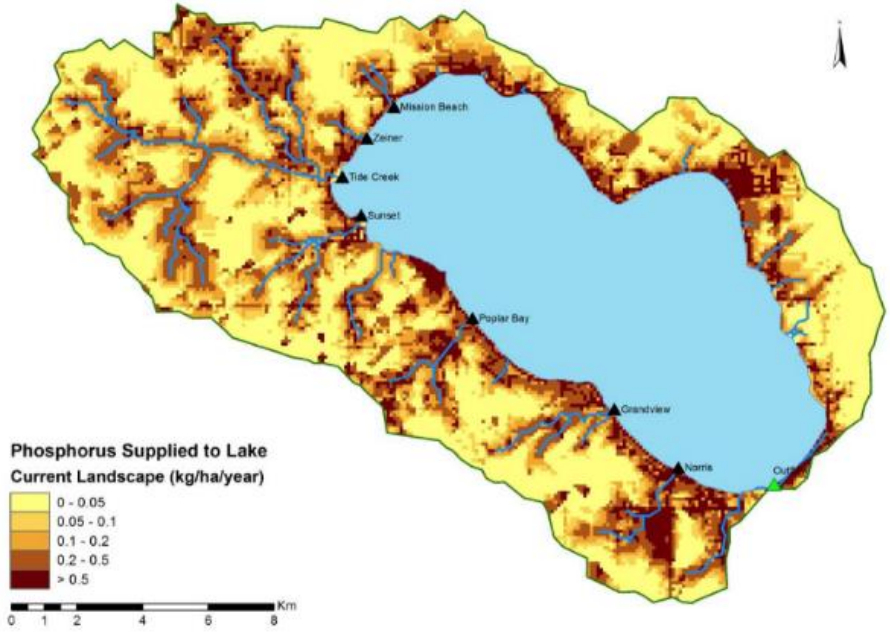
The ABMI simulation also found that relative to the current development conditions (FIGURE C7), the amounts of P that will be exported into Pigeon Lake from the watershed depend on the intensity of future development, though significant reductions were possible in all scenarios if riparian area protection and restoration occurred. Overall, although the ABMI model only accounts for the P input from surface runoff, it provides an effective management tool for evaluating the relative contribution of P from different sources in the watershed as well as for quantifying the efficiency of land management practices.

At the watershed level, P reduction initiatives should focus on reducing diffuse, point-source and sewage inputs of P (FIGURE C1). While diffuse P sources may be the most challenging to effectively reduce and measure success, they represent nearly half of the external P loading into Pigeon Lake and are the largest controllable portion; thus, it is important to explore management options. Sources of atmospheric deposition and groundwater influx of P require further determination; however, implementing beneficial management practices such as conservation tillage practices may help reduce the volatility of cultivated soils to wind erosion, reduce overland transfer of nutrients, and reduction of excess P application to the land may reduce downward migration to groundwater.

Plan Implications

- About 25% of the P inputs into Pigeon Lake come from watershed-level sources making the land cover types and land use activities within the watershed highly influential to the water quality and quantity of the lake. Watershed stewardship and incorporation of Beneficial Management Practices (BMPs; AAFRD 2004) are recommended to decrease both the nutrient concentrations in the inflowing streams and the rates at which overland flow enters the streams.
- The removal of riparian vegetation and watershed tree cover has exacerbated the rates of nutrient export from watershed sources into Pigeon Lake. Modelling has shown that riparian restoration along the lake and stream shores can result in a reduction in external nutrient loading into the water, even when the watershed itself is highly developed. Hence, a riparian and watershed conservation and restoration program should be initiated in the Pigeon Lake watershed, with efforts prioritized in areas of high P loading potential (FIGURE C8).

- Municipalities should adopt riparian setback policies to establish appropriate setbacks from all waterbodies in the watershed to maintain water quality, flood water conveyance and storage, bank stability, and habitat. Tools such as the Riparian Matrix Setback Model (Aquality Environmental Consulting 2010) can be used to manage riparian areas in a local municipality (broad brush approach).
- A significant function of wetlands is their ability to trap and retain nutrients. To increase this function in Pigeon Lake's watershed, wetlands should be conserved and restored. Thus, a list of candidate wetlands for restoration within the watershed should be developed and will streamline watershed improvement efforts under the Alberta Wetland Policy. Also, riparian buffers around wetlands are required to protect function.
- The coverage and ecological condition of natural land cover (e.g., forests and wetlands) should be maintained or improved. Conversion of remaining ecological lands to agricultural, residential, or recreational areas should be limited.
- Diffuse runoff over altered (agricultural, developed, etc.) lands comprises a significant portion of external P loadings into Pigeon Lake. Current practice does not allow for enforcement or rejection of activity based on cumulative impacts decision making. In the context of Pigeon Lake, development decisions should be thoroughly assessed to ensure that there is either a decrease or, at a minimum, no increase in nutrient export relative to current conditions. Municipal governments must ensure their review of impacts is neither too narrow nor too broad. Approvals for any work should also consider the increases to nutrient and sediment loading as a result of alterations in pre-development hydrology and watershed-level land use changes.
- Adoption of clean runoff BMPs by individual land owners and municipalities into their developments and operations will contribute to water quality improvement and increase water use efficiency.
- In agricultural lands, existing BMPs that promote soil health and responsible resource use should be continued and encouraged (e.g., AAFRD 2004). Conservation tillage programs can reduce the erodibility of soils and the subsequent potential for export via runoff. Similarly, precision agriculture approaches can be taken to avoid the export of excess nutrients off the land and into waterways by care



fully controlling the application rate, timing, and placement of inorganic fertilizers or manure. BMPs specific to ranching include reducing the intensity of grazing and trampling near riparian areas and providing water alternatives away from streams.

- In residential areas (i.e. Lakeshore developments, county residential) BMPs and implementation of Low Impact Development (LID) practices in existing and new developments will be very important to reduce P export. Principles and practices for implementing LID practices at Pigeon Lake are detailed in in the Alberta Clean Runoff Action Guide (PLWA and ALIDP 2016). Incorporating low-phosphorus development standards in Land Use Bylaws and statutory plans will be very important to achieve compliance on the part of individual land owners and developers.
- Removal of septic fields, in addition to upgrades to wastewater infrastructure of cottages and public use areas (where antiquated or

ineffective) should be encouraged to improve the water quality of Pigeon Lake. Although sewage inputs to the lake are a relatively small source of P, reducing seepage into the lake will have benefits to water quality since the P forms present in sewage are largely bioavailable for algal and plant uptake (i.e., dissolved forms of P).

- BMPs should include prohibitions on cosmetic fertilizers. A previous initiative to restrict the application of fertilizers and pesticides for cosmetic purposes in the watershed was well-supported by shoreline residents and has been implemented by municipalities throughout the watershed.
- While the dust deposition into Pigeon Lake is very technically difficult to control, atmospheric sources of P represent a significant component of the nutrient inputs to the lake. As such, the source of these inputs, as well as its form and bioavailability, should be better studied to understand where reductions are possible.

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2 SUMMARY OF THE SCIENCE: THE SHORELINE

Riparian Health

Riparian areas are biologically rich and productive areas at the edges of lakes, wetlands and streams. Riparian areas are important habitat and provide essential ecosystem functions to protect the lake's health.

In 2002 and 2008, low-altitude videography was used to conduct a riparian health assessment of Pigeon Lake (SRD 2008). The riparian area surveyed included the collective near-shore area consisting of the lake's shallow water zone (littoral) and the strip of public lakeshore, and the immediately adjacent private land that surrounds the lake. Criteria evaluated to assess riparian "health" included proportion of area covered by natural vegetation, presence of cattails (*Typha latifolia*) and bulrushes (*Scirpus* spp. and *Schoenoplectus* spp.), abundance of trees and shrubs, and the amount of human-caused vegetation removal or physical alteration. The shoreline was divided into consecutive sections and these criteria were used to classify each section into one of three impairment categories: healthy, moderately impaired, or highly impaired. The total length of shoreline in each impairment category was calculated and expressed as a percentage of the total shoreline length.

In both sampling years, the majority of Pigeon Lake's shoreline (65%) was classified as being highly impaired. In 2002, 24% of the shoreline was considered to be healthy and the remaining 11% was moderately impaired, while in 2008 (FIGURE C8) there was a slight improvement in shoreline health, with 29% of the shoreline classified as healthy and 6% classified as moderately impaired. This improvement is attributed to land purchases by the Government of Alberta along the northwest shore, though some improvement in riparian health was offset by poorer health scores elsewhere along the lake. The extensive impairment around Pigeon Lake is associated with the extensive removal of riparian vegetation and shoreline modification (e.g., maintenance of beaches, erosion control structures, installations of docks, boat lifts and marinas, and the construction of cottages adjacent to the shoreline). Notably, sections of highly impaired shoreline were very long and continuous, with healthier sections being largely restricted to areas of minimal cottage development on the northwest and east shores at the Provincial Park and First Nations Reserve (FIGURE C8)

The Government of Alberta has recommended that a similar shoreline assessment should be performed every five years on Pigeon Lake to monitor the extent and integrity of remaining riparian areas (SRD 2008). In addition, assessments of both the health of the lake and tributary riparian areas would highlight priority areas for protection and restoration.

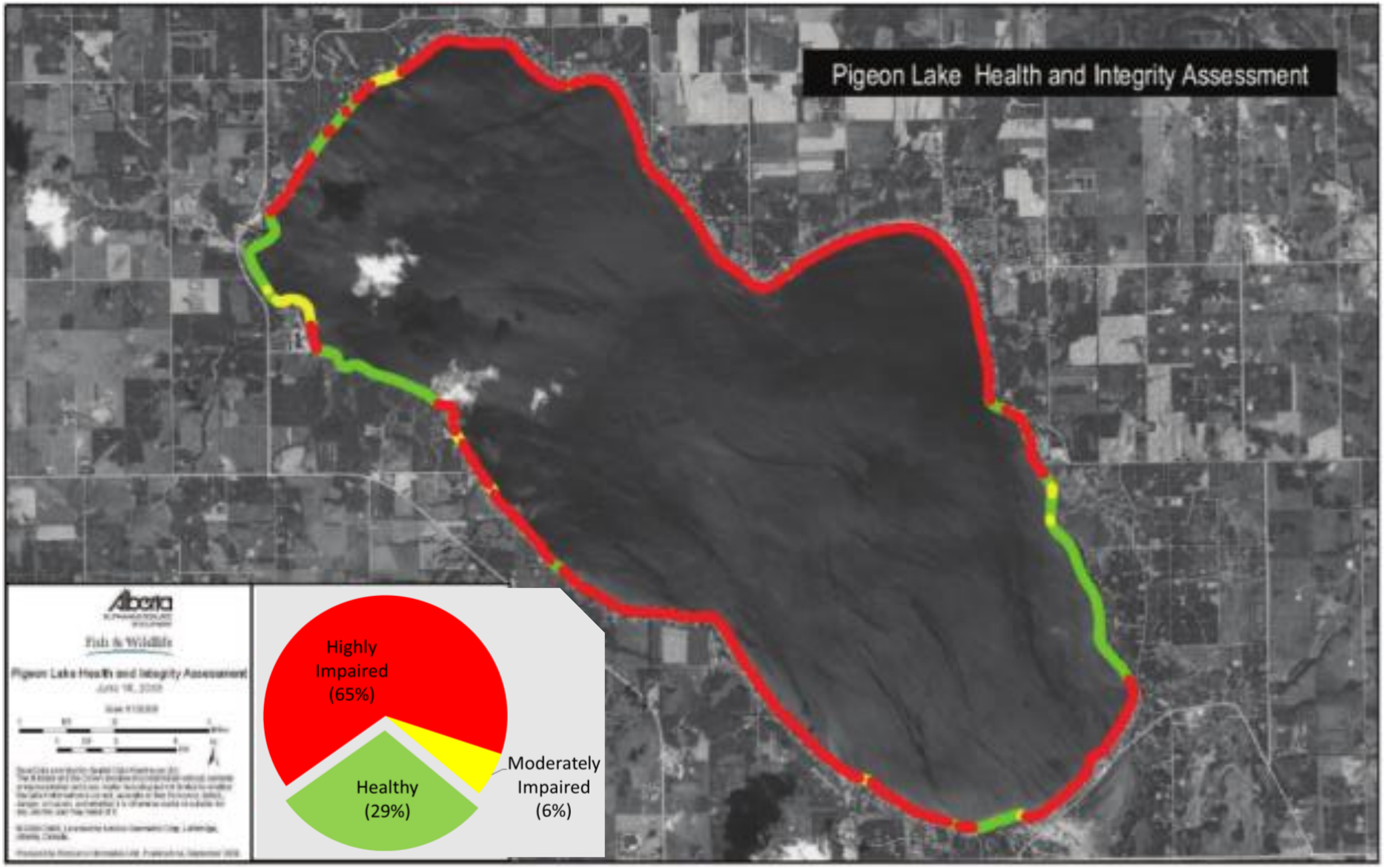

Figure C8: Pigeon Lake shoreline integrity assessment results from a June 2008 survey, indicating the extent of lakeshore degradation around the lake (SRD 2008).

Near-shore Vegetation

Aquatic vegetation (i.e., near-shore within the littoral zone) perform a wide range of ecologically-important functions, including nutrient and contaminant sequestration, shoreline stabilization, buffering water flows, and supporting rich biodiversity. Destruction of littoral habitats entails some loss of these ecological services and will have negative consequences for the biological communities of Pigeon Lake. For example, Northern Pike (*Esox lucius*), hide among vegetation such as cattails and bulrushes to ambush their prey, and rely heavily on the vegetation for spawning and rearing. Removal of the littoral vegetation compromises not only Northern Pike success but may also adversely affect other trophic levels in Pigeon Lake.

The distribution of littoral vegetation around Pigeon Lake is dependent on the extent of shoreline development and substrate type, with finer sediments and sheltered areas being most suitable for growth of aquatic vegetation. Submersed aquatic vegetation communities occur along much of Pigeon Lake's shore, with community composition and density influenced by factors such as water depth, turbulence, and sediment accumulation patterns.

In general, vegetation cover is related to the extent of shoreline development, with the lowest cover occurring in areas of high cottage density. However, no formal vegetation mapping of Pigeon Lake has occurred since the early 1980s. Continued disturbance and vegetation control activities further alter and limit the distribution of both riparian and aquatic vegetation communities, to the detriment of a healthy ecosystem.

Plants commonly found in Pigeon Lake's littoral and riparian vegetation communities are listed in TABLE C1.

Table C1: List of plants typical of Pigeon Lake's littoral and riparian vegetation communities.

Habitat	Growth Form	Common Name	Scientific Name
Littoral	Floating-leaved	Bur-reeds	*Sparaganium* spp.
Littoral	Floating-leaved	Common Duckweed	*Lemna minor*
Littoral	Floating-leaved	Star Duckweed	*Lemna trisulca*
Littoral	Floating-leaved	Variegated Pond-lily	*Nuphar variegatum*
Littoral	Floating-leaved	Water Smartweed	*Persicaria amphibia*
Littoral	Submerged	Autumn Water-starwort	*Callitriche hermaphroditica*
Littoral	Submerged	Common Bladderwort	*Utricularia vulgaris*
Littoral	Submerged	Common Water Moss	*Fontinalis* spp.
Littoral	Submerged	Coontail	*Ceratophyllum demersum*
Littoral	Submerged	Flat-stem Pondweed	*Potamogeton zosteriformis*
Littoral	Submerged	Fries' Pondweed	*Potamogeton friesii*
Littoral	Submerged	Lesser Pondweed	*Potamogeton pusillus*
Littoral	Submerged	Northern Watermilfoil	*Myriophyllum sibiricum*
Littoral	Submerged	Pondweeds	*Potamogeton* spp.
Littoral	Submerged	Richardson's Pondweed	*Potamogeton richardsonii*
Littoral	Submerged	Sago Pondweed	*Stuckenia pectinata*
Littoral	Submerged	Sheathed Pondweed	*Stuckenia vaginata*
Littoral	Submerged	Slender Water-nymph	*Najas flexilis*
Littoral	Submerged	Stonewort	*Chara* spp.

Habitat	Growth Form	Common Name	Scientific Name
Littoral	Submerged	Various-leaved Pondweed	*Potamogeton gramineus*
Littoral	Submerged	Water Buttercup	*Ranunculus aquatilis*
Littoral	Submerged	White-stem Pondweed	*Potamogeton praelongus*
Littoral	Submerged	Widgeon Grass	*Ruppia cirrhosa*
Riparian	Emergent Macrophyte	Bluejoint	*Calamagrostis canadensis*
Riparian	Emergent Macrophyte	Common Cattail	*Typha latifolia*
Riparian	Emergent Macrophyte	Creeping Spike-rush	*Eleocharis palustris*
Riparian	Emergent Macrophyte	Horsetails	*Equisetum* spp.
Riparian	Emergent Macrophyte	Knotted Rush	*Juncus nodosus*
Riparian	Emergent Macrophyte	Sedges	*Carex* spp.
Riparian	Emergent Macrophyte	Sloughgrass	*Beckmannia syzigachne*
Riparian	Emergent Macrophyte	Small-fruited Bulrush	*Scirpus microcarpus*
Riparian	Emergent Macrophyte	Soft-stem Bulrush	*Schoenoplectus tabernaemontani*
Riparian	Emergent Macrophyte	Wire Rush	*Juncus balticus*
Riparian	Forb	American Brooklime	*Veronica americana*
Riparian	Forb	Arum-leaved Arrowhead	*Sagittaria cuneata*
Riparian	Forb	Celery-leaved Buttercup	*Ranunculus sceleratus*
Riparian	Forb	Docks	*Rumex* spp.
Riparian	Forb	Fireweed	*Chamerion angustifolium*
Riparian	Forb	Marsh Ragwort	*Senecio congestus*
Riparian	Forb	Marsh Yellow Cress	*Rorippa palustris*
Riparian	Forb	Nodding Beggar-ticks	*Bidens cernua*
Riparian	Forb	Northern Stitchwort	*Stellaria borealis*
Riparian	Forb	Northern Willow-herb	*Epilobium ciliatum*
Riparian	Forb	Pale Persicaria	*Persicaria lapathifolium*
Riparian	Forb	Philadelphia Fleabane	*Erigeron philadelphicus*
Riparian	Forb	Purple-stemmed Aster	*Symphyotrichum puniceum*
Riparian	Forb	Silverweed	*Potentilla anserina*
Riparian	Forb	Stinging Nettle	*Urtica dioica*
Riparian	Forb	Water Hemlock	*Cicuta maculata*
Riparian	Forb	Water Parsnip	*Sium suave*
Riparian	Forb	Western Willow Aster	*Symphyotrichum lanceolatum*
Riparian	Forb	Wild Mint	*Mentha arvensis*
Riparian	Forb	Yellow Avens	*Geum aleppicum*
Riparian	Forb	Yellow Water Crowfoot	*Ranunculus gmelinii*
Riparian	Non-native Forb (Weed)	Bladder Campion	*Silene vulgaris*
Riparian	Non-native Forb (Weed)	Canada Thistle	*Cirsium arvense*
Riparian	Non-native Forb (Weed)	Caraway	*Carum carvi*
Riparian	Non-native Forb (Weed)	Common Groundsel	*Senecio vulgaris*
Riparian	Non-native Forb (Weed)	Common Mullein	*Verbascum thapsus*
Riparian	Non-native Forb (Weed)	Common Tansy	*Tanacetum vulgaris*

Habitat	Growth Form	Common Name	Scientific Name
Riparian	Non-native Forb (Weed)	Common Toadflax	*Linaria vulgaris*
Riparian	Non-native Forb (Weed)	Creeping Bellflower	*Campanula rapunculoides*
Riparian	Non-native Forb (Weed)	Himalayan Balsam	*Impatiens glandulifera*
Riparian	Non-native Forb (Weed)	Leafy Spurge	*Euphorbia esula*
Riparian	Non-native Forb (Weed)	Meadow Hawkweed	*Hieracium caespitosum*
Riparian	Non-native Forb (Weed)	Orange Hawkweed	*Hieracium auranticum*
Riparian	Non-native Forb (Weed)	Ox-eye Daisy	*Leucanthemum vulgare*
Riparian	Non-native Forb (Weed)	Perennial Sow-thistle	*Sonchus arvensis*
Riparian	Non-native Forb (Weed)	Purple Loosestrife (rare)	*Lythrum salicaria*
Riparian	Non-native Forb (Weed)	Scentless Chamomile	*Anthemis arvensis*
Riparian	Non-native Forb (Weed)	Stinkweed	*Thlaspi arvense*
Riparian	Non-native Forb (Weed)	Tansy Ragwort	*Senecio jacobaea*
Riparian	Non-native Forb (Weed)	White Cockle	*Silene latifolia*
Riparian	Shrub	Alders	*Alnus* spp.
Riparian	Shrub	Bush Cranberries	*Viburnum* spp.
Riparian	Shrub	Chokecherry	*Prunus virginiana*
Riparian	Shrub	Currants and Gooseberries	*Ribes* spp.
Riparian	Shrub	Prickly Rose	*Rosa acicularis*
Riparian	Shrub	Raspberry	*Rubus idaeus*
Riparian	Shrub	Red Osier Dogwood	*Cornus sericea*
Riparian	Shrub	Saskatoon	*Amelanchier alnifolia*
Riparian	Shrub	Willows	*Salix* spp.
Riparian	Tree	Balsam Poplar	*Populus balsamifera*
Riparian	Tree	Paper Birch	*Betula papyrifera*
Riparian	Tree	Trembling Aspen	*Populus tremuloides*
Riparian	Tree	White Spruce	*Picea glauca*

Invasive Species

Existing and ongoing threat: Himalayan Balsam (*Impatiens glandulifera*), a plant listed as a Prohibited Noxious Weed under Alberta's Weed Control Act, was discovered on Pigeon Lake shorelines in the early 2000's. The plant's fast growth rates and aggressive seed dispersal mechanism (including transport in lake water) allowed it to rapidly invade lakeshores and replace native riparian vegetation. Himalayan Balsam infestations can increase shoreline erosion because the plants die off every year (leaving the shoreline bare and exposed for part of the year) and their shallow root systems are ineffective at retaining soil. An action plan for the eradication of this plant from the watershed was developed in 2009, and the Pigeon Lake shoreline was tentatively declared free of Himalayan Balsam in 2015. An ongoing monitoring and control effort is continuing to prevent a repeat infestation and support the re-establishment of native riparian vegetation. Other invasive plants such as Common Tansy and Creeping Bell Flower are rapidly becoming established in the riparian area. Non-chemical actions should be taken by all lakeside communities to combat this invasion.

Emerging Threats: Waterbodies are under constant threat from the unintentional introduction of invasive species. These organisms, whether they are plants, fish or invertebrates, can cause significant damage to the lake's ecosystem. Other areas in Alberta have already seen the effects of waterbody-choking plants such as Eurasian Watermilfoil or Flowering Rush and fish such as Prussian Carp, while species such as zebra and quagga mussels have caused immense devastation elsewhere in Canada. The introduction of these species

was the result of improper care of boats and other recreational items and by the inter-lake transfer of live fish. Extreme care must be taken with water vessels (boats, canoes, fishing gear, etc.) to ensure removal of any plants or animals. The *Clean, Drain, Dry* program has been introduced as a means of protecting lakes from these invasive species.

Some of the species of concern are:

- Zebra mussels (*Dreissnea polymorpha*) and quagga mussels (*D. bugensis*) were introduced to North America via ballast water from Eurasia and have severely disrupted aquatic ecosystems in the Great Lakes Region and elsewhere. These organisms attach to hard surfaces (e.g., boat hulls or propellers) in very high densities and their veligers (larvae) are readily transported in bait containers, live wells and internal ballast tanks. Thus, boats are the primary form of zebra and quagga mussel introduction to new waterbodies. In addition to disrupting aquatic food webs, zebra and quagga mussels pose a considerable nuisance to recreation and impediment to infrastructure; once colonies have established, they are extremely difficult to eradicate. Zebra and quagga mussels have not been detected in Pigeon Lake as of 2017, but similar to Eurasian Watermilfoil, early detection and action is necessary to prevent infestation and potentially irreversible consequences.
- Eurasian Watermilfoil (*Myriophyllum spicatum*), listed as a Prohibited Noxious Weed in Alberta, is a rooted aquatic plant that can be highly disruptive to lake ecosystems. It is an unpalatable food source for native waterfowl and fish, and its rapid growth and ability to grow from stem fragments allow it to out-compete native aquatic vegetation. The plant grows close to the water surface and can restrict swimming and boating access, as well as block water outlets. Eurasian Watermilfoil fragments are easily spread between waterbodies via boats, trailers, anchors and propellers. Lakes in British Columbia, Ontario and Quebec have already become infested. Although the plant has not been found in Pigeon Lake as of yet, some localized infestations exist elsewhere in Alberta. Early detection and a proactive boat maintenance program (clean, drain and dry) will be critical to prevent a serious lake-wide threat in Pigeon Lake.
- Flowering Rush (*Butomus umbellatus*), also listed as a Prohibited Noxious Weed in Alberta, is an aquatic plant that can severely disrupt wetland, river and lake ecosystems. It resembles a large sedge or bulrush but has showy pink flowers and can grow in both emergent and submerged forms. The plant has an extensive root system and – in addition to producing seeds – can reproduce vegetatively from root fragments if they are broken. These root fragments can travel long distances in water and create dense colonies where they establish, crowding out and displacing native aquatic vegetation. Flowering Rush can interfere with boat propellers and its large, dense stands can restrict waterbody access for a variety of lake users. Flowering Rush was sold commercially as an ornamental garden plant but has established in some lakes, rivers, creeks, irrigation canals, and stormwater ponds elsewhere in Alberta. This pant has not yet been observed in Pigeon Lake, though prevention of a Flowering Rush infestation will require early detection and proper control techniques if any plants establish in the waterbody.
- Prussian Carp (*Carassius gibelio*) are relatives of common goldfish and pose a serious threat to Alberta freshwater ecosystems. These fish are extremely hardy, able to survive in conditions of very poor water quality which would be intolerable for other fish species. Additionally, Prussian carp can reproduce asexually and effectively create clones of themselves, contributing to rapid population increases. The source of Prussian carp introduction into Alberta's aquatic ecosystems is unclear, though the impacts on aquatic ecosystems of these fish are well-documented. Prussian carp out-compete native fish species for food and habitat resources and can cause fundamental changes in the aquatic invertebrate communities, possibly leading to trophic collapses. There are established breeding populations in some ponds, lakes and rivers in Alberta, but no fish have been reported in Pigeon Lake as of 2017. Eradication of Prussian carp is very difficult once they are established in a

waterbody; hence, education efforts and prevention of introduction into Pigeon Lake are paramount.

Riparian BMPs

Riparian BMPs involve actions that can be taken by land owners and users within the Pigeon Lake watershed to improve the water quality of the lake and streams. These may include:

- Avoiding where possible activities that involve the removal of riparian vegetation such as mowing, trimming, herbicide applications, cultivating, and land clearing. Maintaining natural vegetation cover on shores is preferred to artificial armoring and modification of shorelines.
- Educating watershed property owners and lake visitors about the importance of littoral vegetation. The current perception of many is that most aquatic plants are all "weeds" and are a nuisance to lake users. However, educating the public on the ecological value of aquatic vegetation is important for the maintenance and improvement of these areas.
- Educating lake users and residents on how to recognize aquatic invasive species is critical for early detection and eradication.
- Encouraging the use of shared docks and day use areas, instead of individual ones.
- Ensuring adequate naturalized setbacks for upland activities such as residential development, cropping, or livestock grazing. This will include leaving a natural vegetation buffer around waterbodies and streams, reducing grazing intensity and access within riparian areas, and planting additional riparian vegetation.
- Eliminating the use of fertilizers and herbicides along the lakeshore.
- Limiting the use of salts on shoreline roads to limit the increase in lake salinity via runoff.

Plan Implications

- BMPs, such as those highlighted above, should be implemented for riparian areas all around Pigeon Lake. Given the extensive development around the lake, educating property owners and municipalities on riparian stewardship will be essential to ensure continued riparian health and function.
- The lake-wide riparian health assessment program should be continued and updated every five years. The last assessment was in 2008, indicating that Pigeon Lake is overdue for an updated shoreline assessment. This monitoring provides important information on how impaired the lakeshore as a whole is, and will inform where to prioritize riparian restoration efforts.
- A similar riparian assessment and monitoring program should be initiated for the inflowing streams into Pigeon Lake, as the ecological integrity of streams will directly affect that of the lake. This may include sensitive habitat mapping and assessment of littoral vegetation at stream tributaries and other key fish habitat areas.
- Consider a comprehensive inventory of critical fish and wildlife habitats such as Sensitive Habitat Inventory Mapping (e.g., Mason and Knight 2001) to identify sensitive shoreline features and habitats surrounding the lake. The resulting Aquatic Habitat Index can be used to inform local mapping and planning initiatives specific to Pigeon Lake.
- To increase the provision of important ecological functions and services, such as fish production and nutrient sequestration, restoration of riparian vegetation all around Pigeon Lake and along the inflowing streams and tributaries should be made a priority.
- Shoreline restoration and strict environmental controls on future development is necessary. Examples of such tools to implement include a regional plan, inter-municipal development plans and/or municipal bylaws.
    - Lake Shoreline Management Guidelines (e.g., EKILMP 2010) can inform municipal development planning specifically to manage the sensitive shoreline features of Pigeon Lake.
    - Implementation of Low Impact Development practices can greatly reduce the runoff of pollutants from the shoreline into the lake (see Alberta Low Impact Development Partnership).

    - Adoption of Sediment and Erosion Control BMP's and Environmental Construction Operations plans for construction activities near sensitive areas to ensure that contractors identify and mitigate their environmental impacts that may result from their activities.
- Ongoing monitoring and proactive efforts are necessary to prevent the infestation of aquatic and riparian invasive species, at both the citizen and government levels.

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3 SUMMARY OF THE SCIENCE: PIGEON LAKE

Historical Climate and Lake Level Fluctuations

Pigeon Lake is a permanent waterbody and has likely existed for thousands of years; due to its large size and low outflow rates, it has a very long residence time (the amount of time that water will remain in the lake) of >100 years. The watershed of Pigeon Lake is small relative to the lake itself, with a ~2:1 watershed (187 km^2) to lake (96.7 km^2) surface area ratio (FIGURE C3; Table C2). This small drainage basin and large evaporative area makes Pigeon Lake particularly sensitive to climatic variability, with changes to precipitation or evaporative rates having a considerable impact on lake water levels.

Pigeon Lake has a very long residence time (the amount of time that water will remain in the lake) of >100 years.

Table C2: Physical properties of Pigeon Lake and its watershed.

Physical Property	Value
Lake Surface Area	96.7 km^2
Lake Water Volume	603,000,000 m^3
Maximum Depth	9.1 m
Mean Depth	6.2 m
Shoreline Length	46 km
Mean Annual Lake Evaporation	664 mm
Mean Annual Precipitation	534 mm
Mean Annual Inflow	17,000,000 m^3
Mean Residence Time	Greater than 100 Years
Lake Weir Sill Elevation	849.935 m (Above Sea Level)
Watershed Land Drainage Area	187 km^2
Watershed to Lake Area Ratio	2:1

(From Mitchell and Prepas 1990)

Climate varies naturally over seasons and years following general atmospheric patterns (e.g., El Nino Southern Oscillation and the Pacific Decadal Oscillation). For example, FIGURE C9 shows mean annual temperature and precipitation for the Pigeon Lake watershed from 1961 to 2016. (Source: Alberta Agriculture and Forestry (interpolated weather data since 1961 for Alberta townships: https://agriculture.alberta.ca/acis/township-data-viewer.jsp). Mean annual precipitation for this period is 519 mm and mean annual temperature is 2.8°C. For precipitation patterns, there are several episodes of multiyear above average and below average periods: a relatively wet period occurred from 1988 to 1991 and from 1996 to 2001. Drier than normal precipitation consecutive periods (below the long-term mean) were observed from 1966 to 1971 and from 2001 to 2003. Mean annual temperature for the same period is 2.8°C, with values showing an increase over time. Climate change scenarios for the region indicate that an increase in precipitation, warmer temperatures, and particularly less cold winters are expected in the future (Davidson 2010).

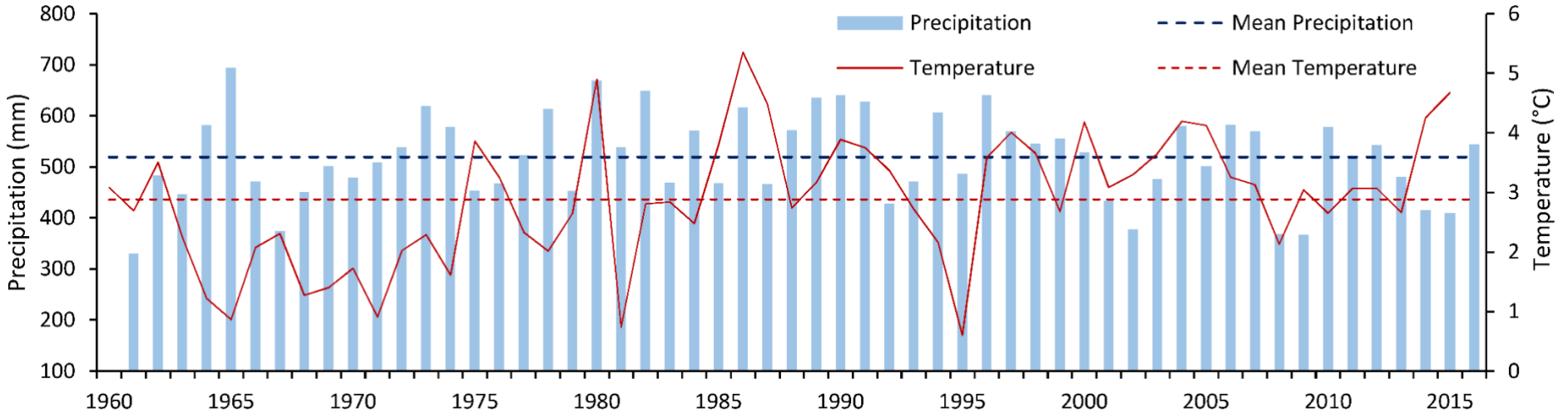

Figure C9. Mean annual temperature and total annual precipitation for the Pigeon Lake watershed.

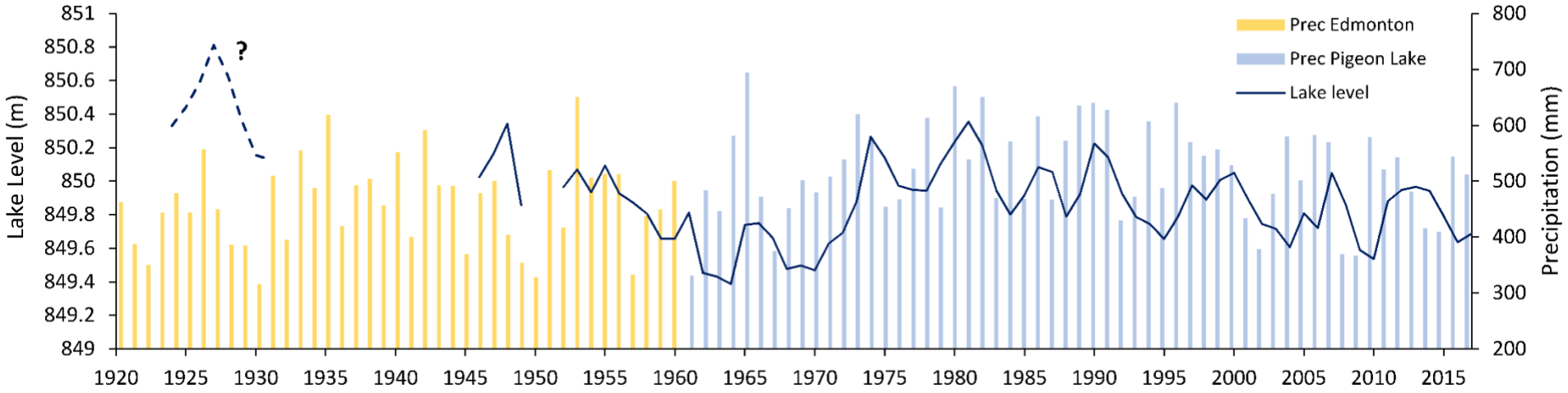

Figure C10. Pigeon Lake mean annual water levels and annual precipitation from 1920 to 2016.

Pigeon Lake historic annual precipitation and mean annual lake levels are shown in FIGURE C10. The annual precipitation from 1920 to 1960 is for the City of Edmonton (yellow bars) and from 1961-2016, shows when climate data became available for Pigeon Lake (blue bars). Data sources include Alberta Environment and Parks, Unpublished data (lake levels for Pigeon Lake); Environment and Climate Change Canada City of Edmonton precipitation data (http://climate.weather.gc.ca/); and Alberta Agriculture and Forestry (https://agriculture.alberta.ca/acis/township-data-viewer.jsp) Pigeon Lake watershed precipitation data.

Pigeon Lake water levels tend to rise and fall in response to cumulative wet and dry precipitation cycles. For example, a 7-year (1967 to 1973) steady increase in annual precipitation resulted in a 5-year (1970 to 1974) rise in Pigeon Lake mean annual water levels. Conversely a 4-year (1999 to 2002) annual precipitation decline caused Pigeon Lake mean annual water levels to decline from 2000 to 2004.

Intermittent water levels have been recorded for Pigeon Lake since 1924 with continuous daily water level monitoring from 1972 to present by Water Survey Canada. Lake levels prior to 1946 were omitted from the analysis because they were based on an assumed datum and could not be reliably converted to geodetic elevations.

Lake levels have not significantly decreased over time at the 95% confidence level during the period 1946-2017, as shown in Figure C11 (p-test = 0.414 and trend slope = -0.001). The shaded box represents the range of most (90 percent) of the historical data (5th and 95th percentiles). The historical data was outside of this range 10 percent of the time. The horizontal dashed line represents the long term median elevation (849.874 m) of the weir sill at the outlet of Pigeon Lake.

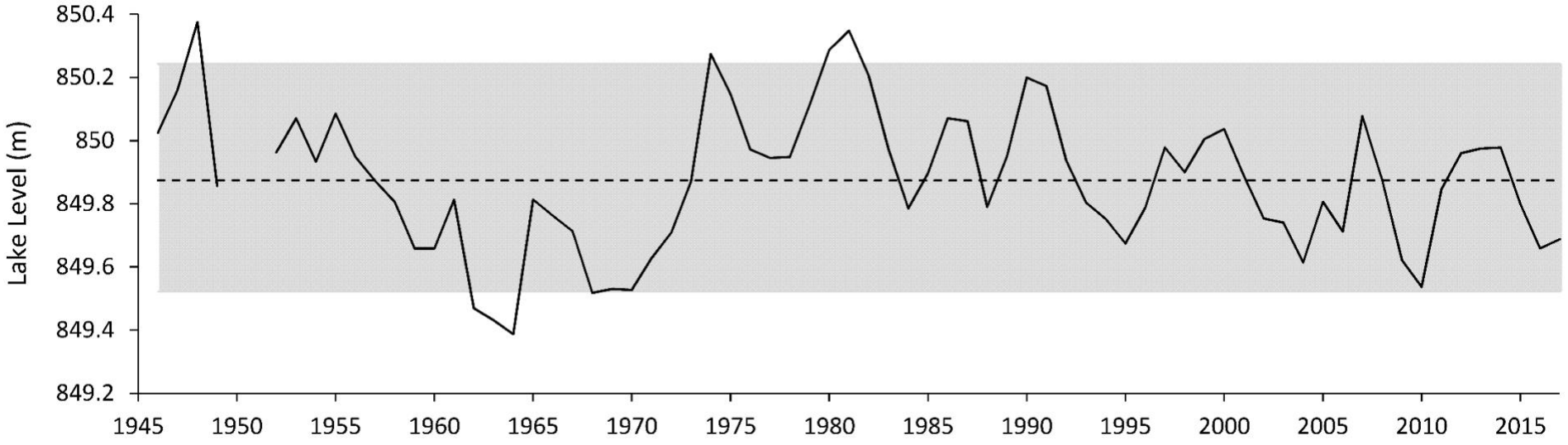

Figure C11: Pigeon Lake mean water level trends (1945-2016). The shaded box represents 5th and 95th percentiles. The horizontal dashed line represents the long-term median elevation (849.874 m) of the weir sill at the outlet of Pigeon Lake.

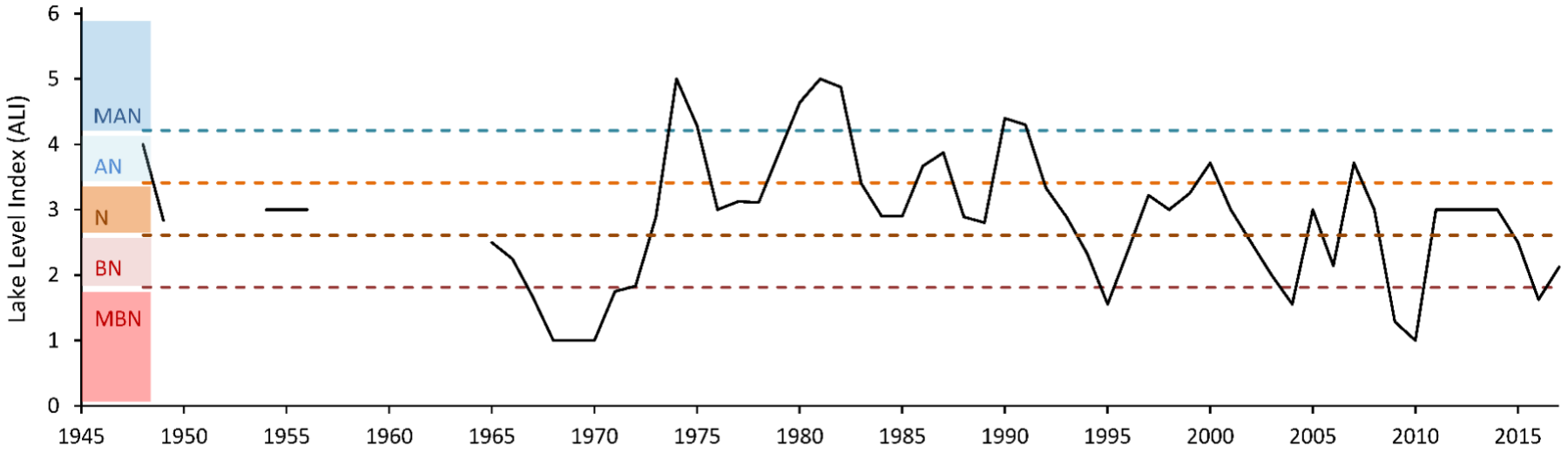

Figure C12. Lake Level Index for Pigeon Lake (1946-2017). Colored areas indicated the range of values for each of the five categories: MAN (Much Above Normal), AN (Above Normal), N (Normal), BN (Below Normal), MBN (Much Below Normal). Note that the index does not include those years with less than 3 lake level measurements.

Alberta Environment and Parks developed the "Alberta Lake Level Index" (ALI; Islam and Seneka 2015) to evaluate the status of lake levels across the province. This method takes into account intra-annual long-term changes in lake levels and has been proved to work well in lakes with limited measurements per year. Annual ALI values for Pigeon Lake, as well as the corresponding category, are provided in FIGURE C12. Lake level oscillations above and below normal are observed and seem to have followed a 20-year cycle: levels were normal or below normal in the 1950s and 1960s; they were normal to above normal from the early 1970s to the early 1990s; they have been normal to below normal from the early 1990s to 2017. Colored areas indicated the range of values for each of the five categories: MAN (Much Above Normal), AN (Above Normal), N (Normal), BN (Below Normal), MBN (Much Below Normal). Note that the index does not include those years with less than three lake level measurements.

FIGURE C13 shows the percent of time Pigeon Lake historic mean daily water levels from 1945 to 2016 equalled or exceeded a certain water level. For example the 70% exceedance is 849.80 m which means historically Pigeon Lake's mean daily water levels equalled or exceed 849.80 m 70% of the time. The 50% exceedance or median historic water level, is 849.922 m, which is 13 mm below the Pigeon Lake Full Supply Level of 849.935m. The 50% exceedance means historically Pigeon Lake's water levels have been above or equal to 849.922 m 50% of the time and below 849.922 m 50% of the time.

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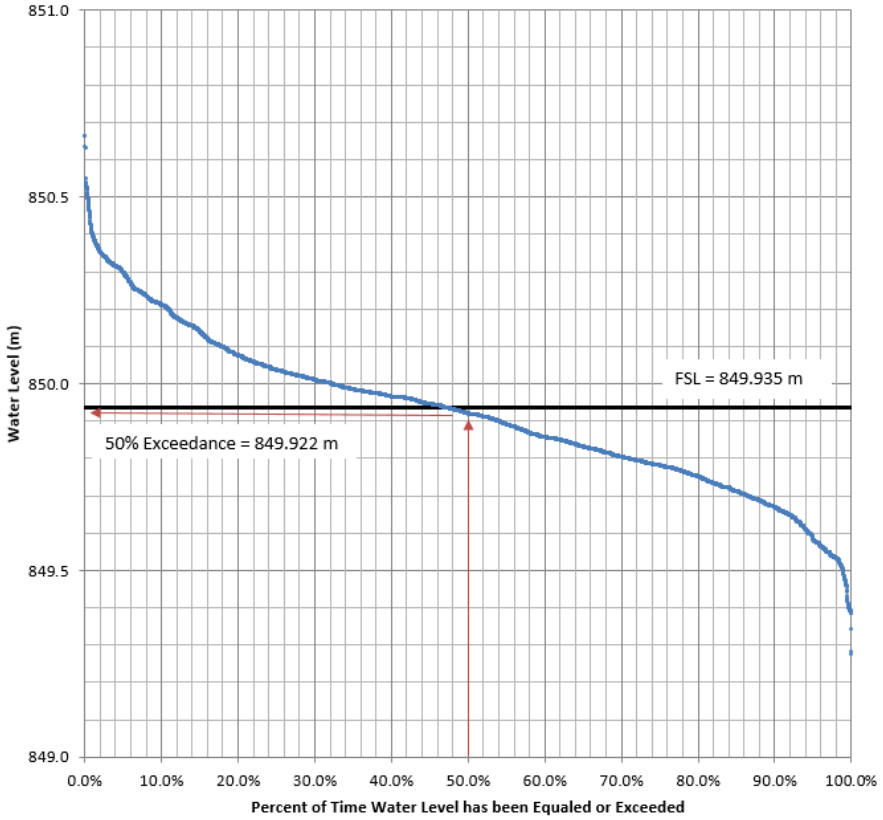

Figure C13: Pigeon Lake Historic Daily Water Levels Percent of Time Equaled or Exceeded (1945-2016).

Worley Parsons modelled the Pigeon Lake water balance from 1993-2009 (17-years) and concluded the mean annual lake input was 684.1 mm, including precipitation (64%), surface runoff (29%) and groundwater contributions (7%). Mean annual lake output was estimated at 701.8 mm and included lake evaporation (93%) and lake outflow (7%, including withdrawals). These results indicated that water losses (mainly through evaporation) exceeded water inputs to the lake, resulting in a mean annual water deficit of 17.7 mm (or 1,730 dam^3/year), matching the observed deficit of 18.7 mm/year for the 1993 to 2009 water balance evaluation period. Alberta Environment and Parks developed a 21-year (1986-2006) Pigeon Lake water balance model (unpublished) and found a mean annual 860 dam^3/year lake volume deficit. The Worley Parsons and Alberta Environment and Parks Pigeon Lake water balance results are summarized in TABLE C3. Although the two Pigeon Lake water balance models were developed independently, simulated different time periods and time intervals, the results were similar. Both concluding Pigeon Lake has similar mean annual surface inflow (19,233 dam^3/year vs 21,539 dam^3/year), groundwater represented a significant inflow component (20% vs. 23%), and there was a net water balance deficit during the simulation period (17.7 mm/year vs 8.5 mm/year) as shown in Table C3. The net deficit suggested by both Pigeon Lake water balance models reflect a relatively short simulation period (17 years vs 21 years) when Pigeon Lake levels were in a downward trend as shown by *Trend 3* in FIGURE C14.

Table C3: Pigeon Lake Water Balance Modelling Results.

Study Author	Worley Parsons		AEP	
Modelled Period	1993-2009		1986-2006	
Total Years	17		21	
	(mm/year)	*(cu.dam/year)*	*(mm/year)*	*(cu.dam/year)*
Inputs:				
Precipitation	438.0	42,653	523.0	50,930
Groundwater Inflow	48.6	4,733	67.1	6,539
Surface Inflow	197.5	19,233	221.2	21,539
Total Inputs	*684.1*	66,619	*811.3*	79,008
Ratio GW to GW&SW	20%		23%	
Outputs:				
Lake Evaporation	657.0	63,979	762.9	74,289
Withdrawals	3.6	347	3.6	355
Lake Discharge	41.3	4,020	53.6	5,224
Total Outputs	*701.8*	68,346	*820.2*	79,868
Net Deficit:	17.7	1,727	8.8	860

FIGURE C14 C14 shows three historic water level trends for Pigeon Lake between 1945 and 2010. Pigeon Lake water levels dropped significantly for 20-years (1950-1970) shown as Trend 1. Pigeon Lake water levels rebounded during the wet years in the 1970s indicated by Trend 2. Trend 3 shows Pigeon Lake in another decreasing cyclic and it was during this time period the two water balance models were developed and why both models correctly demonstrated a net deficit for Pigeon Lake. Both water balance models simulated a relatively short hydrologic time period when Pigeon Lake was in a decreasing trend (Trend 3) therefore the modelling results do not reflect the long-term historic variability of Pigeon Lake climate nor cyclic water level trends (Trends 1 and 2). There is no evidence that the long term average water volume in Pigeon Lake is decreasing beyond historical natural variability

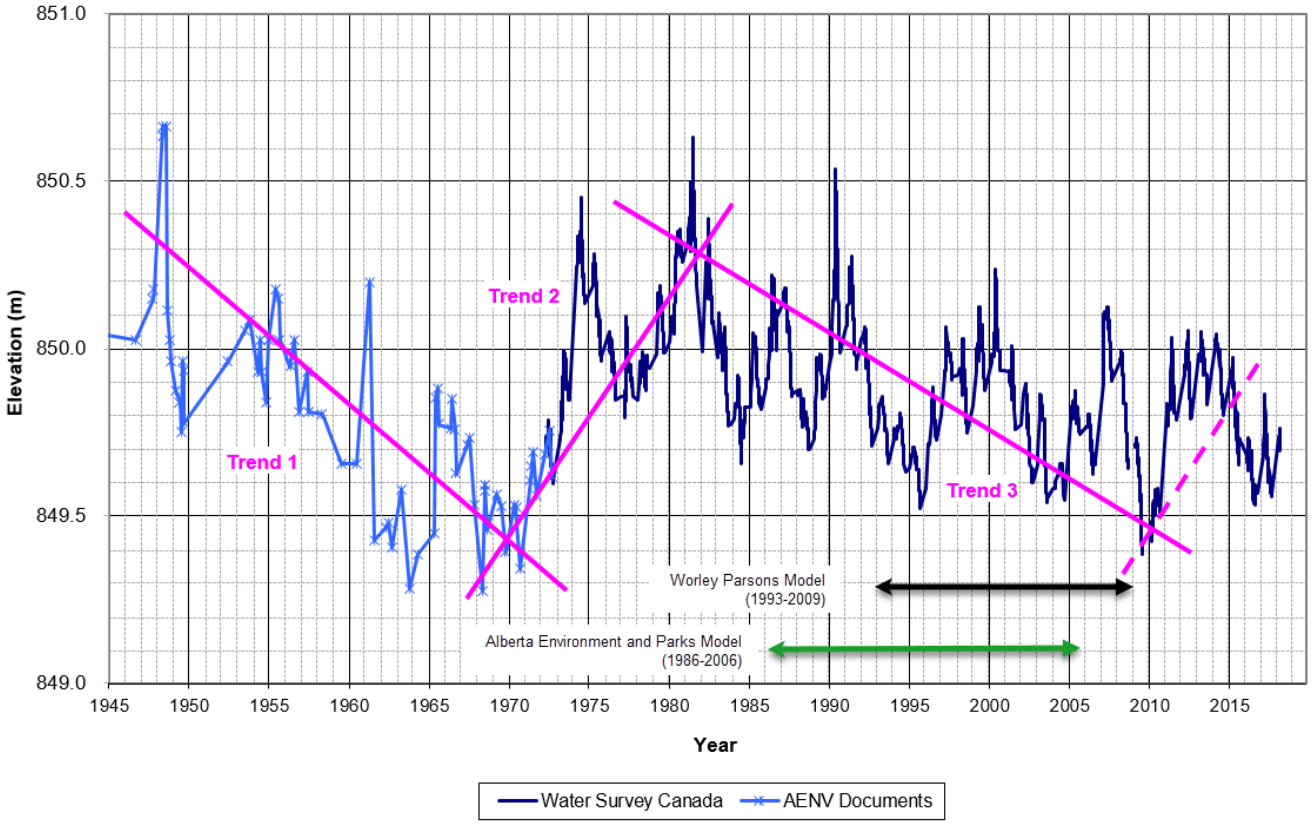

Figure C14: Pigeon Lake Mean Daily Water Level Trends and Water Balance Model Simulation Period.

Overall, extensive historical water level data has demonstrated that Pigeon Lake experiences ongoing water level cycles of both increasing and decreasing trends when considered over a longer time-period as a result of variability in weather patterns (FIGURES C9, C10, C11, C12, C14). In a manner similar to other prairie lakes, the water level varies by approximately 1.3 m. There is no evidence that the long-term average water volume in Pigeon Lake is decreasing beyond historical variability.

The outflow creek that drains Pigeon Lake into the Battle River is fitted with a weir with a sill elevation of 849.935 masl. When the water level reaches this elevation, outflow occurs, including nominal export of nutrients (FIGURES C4, C5). Attempts to maintain water levels above the weir sill elevation may benefit recreational users and may result in the removal of some nutrients from the water column, but issues of nutrient input (both internal and external loadings) would still need to be addressed. Proposals to manage lake levels at

an artificial level above the weir crest elevation entails that supplemental water would have to be introduced into Pigeon Lake from beyond its watershed to increase the lake volume flushing rate (i.e., decrease the lake residence time). Due to the significant regulatory implications and resources required for such a project, further study of the efficacy of such an option should be completed and must address issues such as:

- Implications for downstream flooding and nutrient flushing on water quality of waterbodies downstream of Pigeon Lake.
- Enhanced flood risk for shoreline properties, as well as the potential for ice damage and associated erosion potential.
- Nutrient additions and risk of invasive species from water importation.
- Long-term financial and liability issues for such a project.
- Environmental effects in the water body where the water would be withdrawn from.
- Estimates of nutrient removal recognizing that nutrients concentrations are very low for most of the year and peak only in the months of July, August and September.

Lake Water Quality Studies

Phosphorus is known to be the major nutrient limiting biological growth in lake ecosystems as it is often present in low concentrations relative to other nutrients (e.g., Nitrogen). Consequently, increases in its availability (particularly in the dissolved form) can result in undesirable production of phytoplankton such as cyanobacteria.

Detailed monitoring of P has occurred in Pigeon Lake to determine whether recent cyanobacteria blooms are a response to excess nutrient concentrations in the water. While Pigeon Lake was confirmed to be P-limited relative to N, the blooms are not solely a consequence of external nutrient loading into the lake. Based on the 2014 Pigeon Lake P budget, internal sources of P (internal loading) are estimated to contribute about 57% of the total available P into the lake's water column (FIGURE C1). Mechanisms behind Pigeon Lake P release involve complex chemical and biological reactions and require further study.

Sediment analysis in 2013 detected higher concentrations of dissolved forms of P (such as orthophosphate) in waters near the sediment layer than at the surface, confirming internal release of P from the sediments (Teichreb et al. 2014). Dissolved forms of P are preferentially taken up by phytoplankton and are thought to be released from lake sediments under periodic anoxic conditions associated with minimal wind mixing and de-oxygenation of deeper waters and also from direct uptake from the phytoplankton. Internal P loading can occur even when lake-bottom waters are well-oxygenated, due to warm temperatures facilitating high rates of organic matter decomposition rates and P release.

Chlorophyll-*a* is a photosynthetic pigment produced by phytoplankton and is commonly used to represent phytoplankton biomass. Elevated levels of chlorophyll-*a* indicate high phytoplankton biomass, which are typically caused by an excess of dissolved (bioavailable) nutrients (i.e., PO_4^{3-}) in the water body. This dissolved phosphorus is taken up by phytoplankton, where it becomes part of its biomass. Because of this, a significant amount of phosphorus is stored in phytoplankton. Analysis of chlorophyll-*a* and TP in Pigeon Lake from 1983-2016 show that both parameters fluctuated considerably and, on average, neither had a statistically significant increase over this 33-year period (FIGURES C15, C16). These data indicate that the variability and peaks in P and chlorophyll-*a* may have been higher in recent years, although this requires further examination (e.g., this could be caused by a change in laboratories).

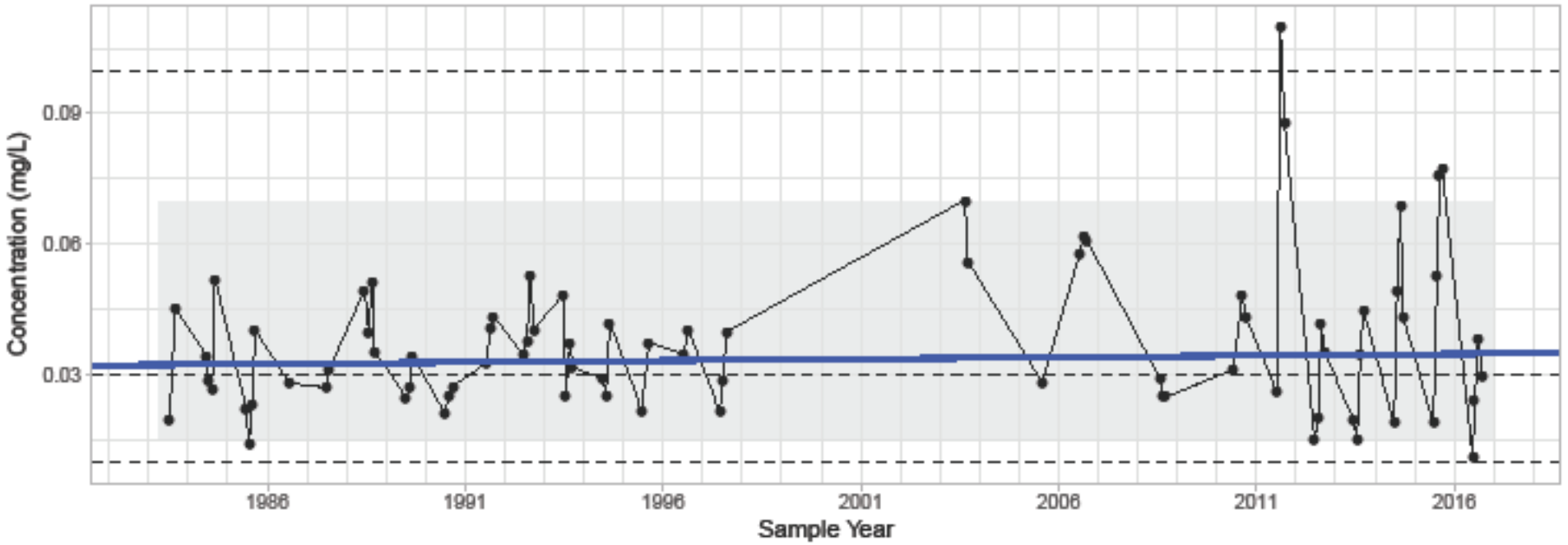

Figure C15: Trend analysis of total phosphorus concentrations in Pigeon Lake over time (1983-2016, June-September data). There is no significant change in total phosphorus concentrations over time (trend test *p*-value = 0.508). The blue line represents the trend line (slope <0.001). The shaded box represents the range of most (90 percent) of the historical data (5th and 95th percentiles). The historical data was outside of this range 10 percent of the time. Horizontal dashed lines represent trophic state cut-offs: oligotrophic <0.01 mg/L; mesotrophic = 0.01 – 0.03 mg/L; eutrophic = 0.03 – 0.1 mg/L; hypereutrophic >0.1 mg/L.

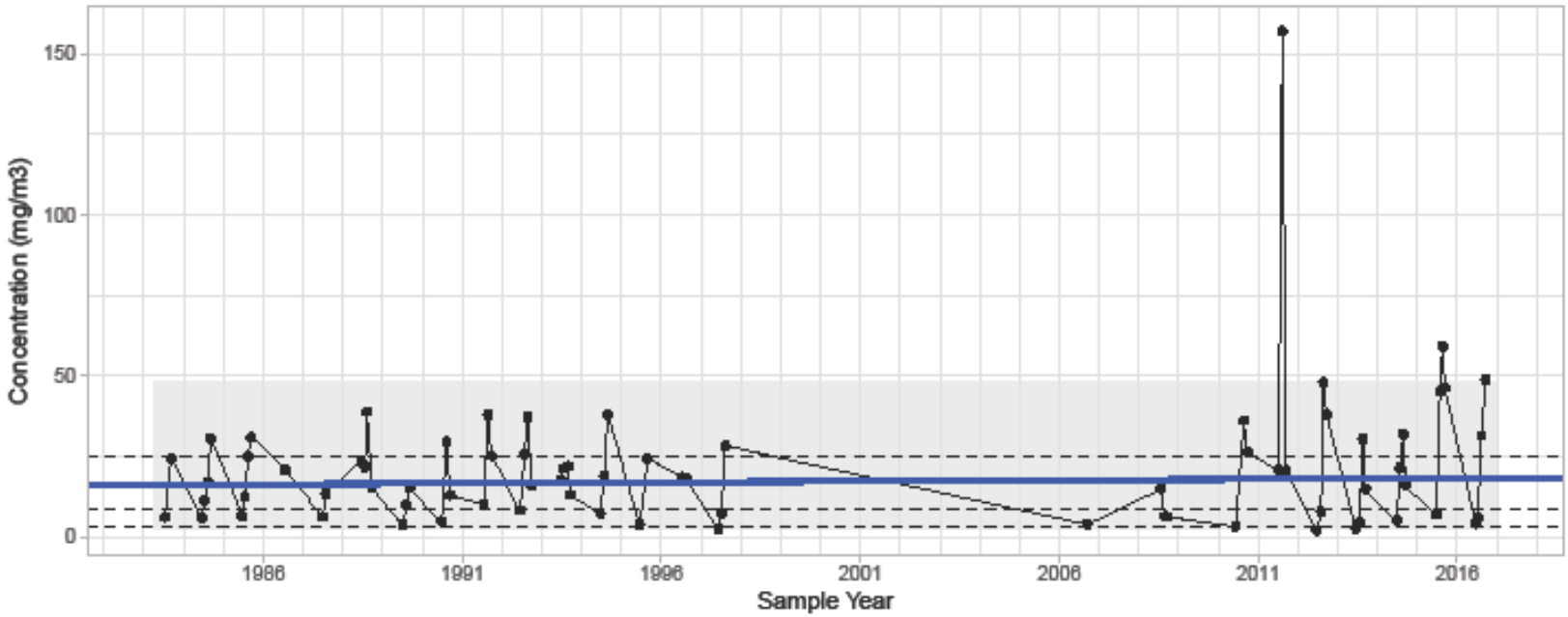

Figure C16: Trend analysis of chlorophyll-*a* concentrations in Pigeon Lake over time (1983-2016, June-September data). There is no significant change in total chlorophyll-*a* concentration over time (trend test *p*-value = 0.529). The blue line represents the trend line (slope = 0.064). The shaded box represents the range of most (90 percent) of the historical data (5^{th} and 95^{th} percentiles). The historical data was outside of this range 10 percent of the time. Horizontal dashed lines represent trophic state cut-offs: oligotrophic <3.5 mg/m^3; mesotrophic = 3.5 – 9 mg/m^3; eutrophic = 9 – 25 mg/m^3; hypereutrophic >25 mg/m^3.

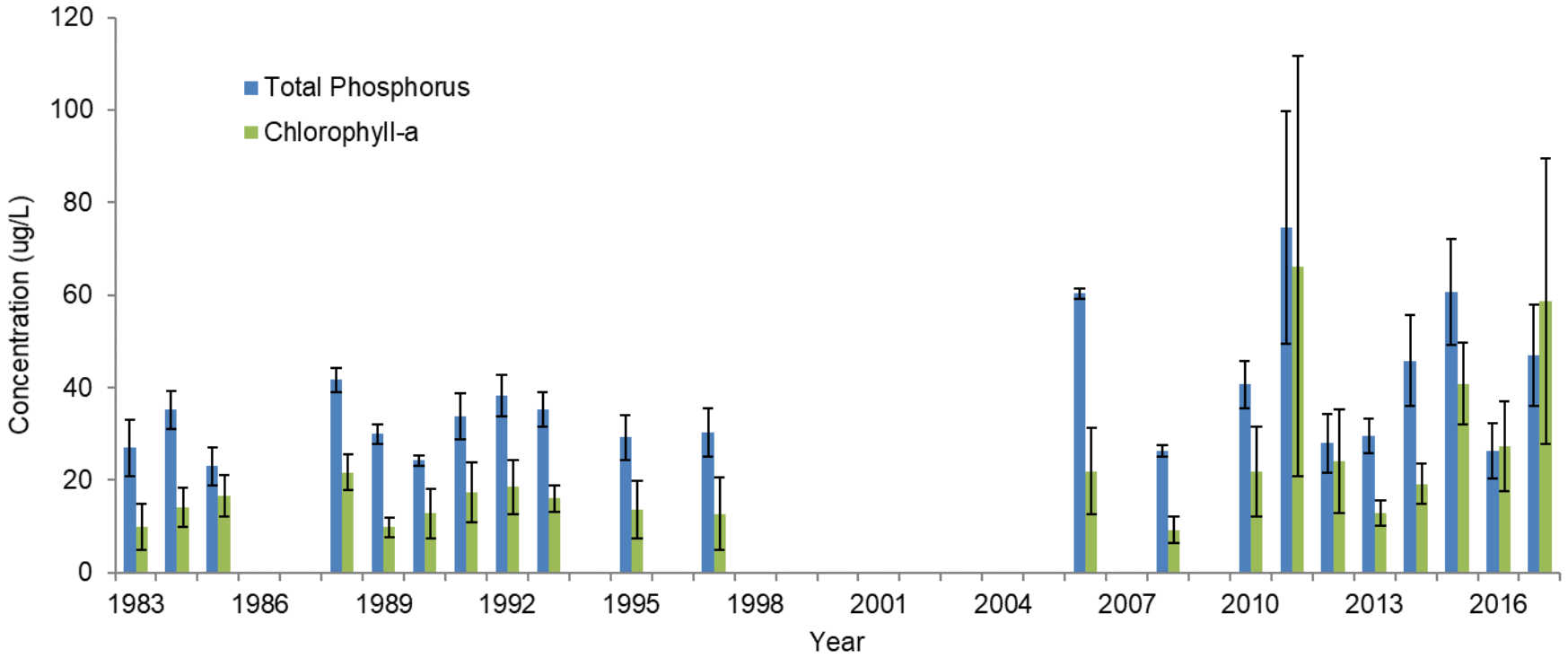

Figure C17: Average annual total phosphorus and chlorophyll-*a* concentrations in Pigeon Lake over time (1983-2017). Note that these variables were analyzed from monthly (May to September) samples taken at 10 sites around the lake, which together represent the conditions of the entire lake. Bars represent standard errors.

FIGURE C17 depicts the variation in average P and chlorophyll-*a* over time. However, there is an incomplete understanding of factors that result in the inter-annual variation in both P and chlorophyll-*a* concentrations. In most years, concentration of TP and chlorophyll-*a* followed an annual pattern, with a steady increase from June and July, peak concentration in August, and a plateau or decrease in September (FIGURE C18). This increase in mid-summer is typical of many shallow lakes, where dissolved nutrients from the decomposition at the lake bottom can be repeatedly distributed to the surface water due to weak thermal stratification.

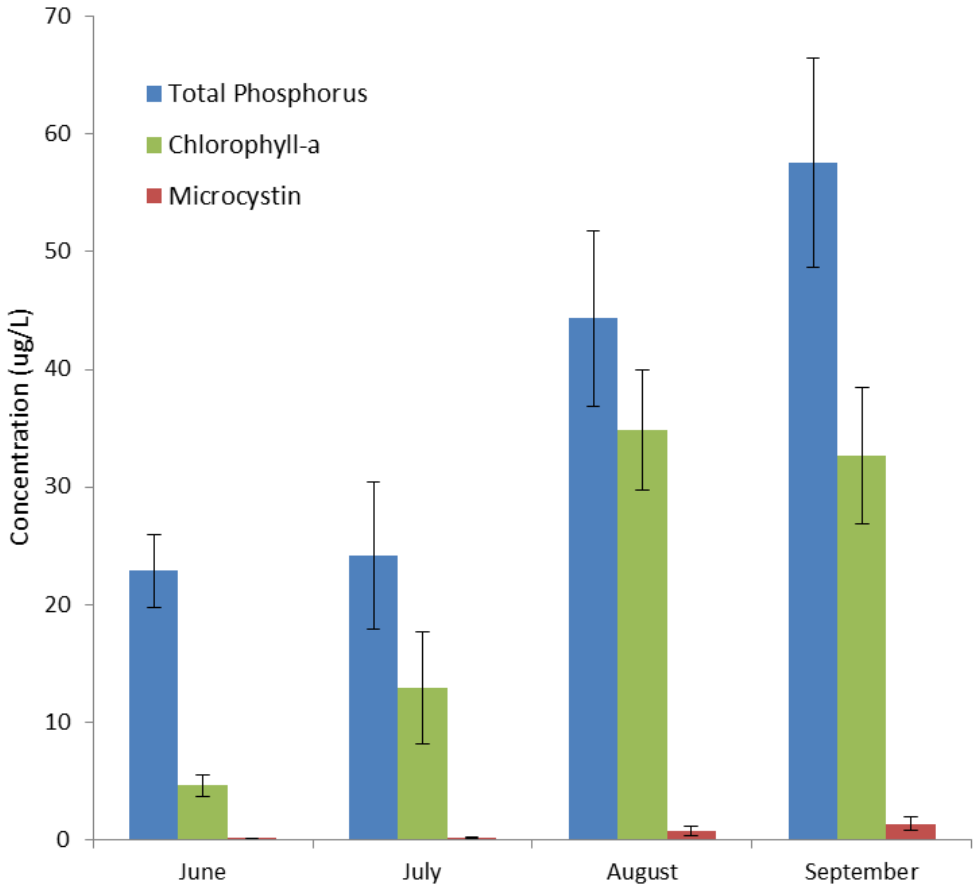

Figure C18: Monthly total phosphorus, chlorophyll-*a*, and microcystin concentrations during the open water season, averaged between 2010-2017. Bars represent standard errors.

Microcystins are toxins produced by certain species of cyanobacteria and sometimes accompany algal blooms. In sufficient concentrations, microcystins can pose a serious threat to human and animal health. In light of the recent cyanobacteria blooms in Pigeon Lake, the Alberta Lake Management Society has conducted annual monitoring of microcystins as part of their whole-lake monitoring program since 2010. Microcystin concentrations were generally low, never exceeding Alberta Surface Water Quality Guidelines for Recreation and Aesthetics (20 µg/L) in open water. Since 2012, Alberta Health Services has been monitoring microcystin concentrations and amount of cyanobacteria consistently at six beaches on Pigeon Lake: Grandview, Ma-Me-O, Mission, Provincial Park, Silver, and Zeiner. As seen in Table C4, these data are very variable, given the dynamic nature of beach ecosystems. Beach microcystin is generally low, except in 2015 when it surpassed the Alberta Guidelines for Recreation and Aesthetics at beach locations at Grandview Beach, Pigeon Lake Provincial Park, and Silver Beach. The amount of total cyanobacteria frequently surpasses the Recreation and Aesthetics Guidelines (100,000 cells/ml) at all beaches, which is not uncommon in Alberta.

Table C4: Microcystin-LR concentration and cyanobacteria cell counts measured at six Pigeon Lake beaches by Alberta Health.

Beach	Minimum value		Average value		Maximum value	
	Microcyst (µg/L)	Cell Count (#/ml)	Microcyst (µg/L)	Cell Count (#/ml)	Microcyst (µg/L)	Cell Count (#/ml)
Grandview	0.03	0	2.32	696,926	59.84	6,787,472
Ma-Me-O	0.03	0	0.88	505,177	13.26	5,610,115
Mission	0.03	0	0.84	583,629	8.25	15,788,134
Prov. Park	0.03	0	2.09	379,846	60.47	3,556,608
Silver	0.03	0	8.92	138,784	483.50	953,094
Zeiner Park	0.05	0	0.73	532,364	15.86	8,040,846

Besides favorable environmental conditions, the success and proliferation of cyanobacteria in Pigeon Lake may be partly attributable to certain aspects of their biology. These include fast reproductive rates, lower light requirements relative to other phytoplankton, decreased palatability to some grazing zooplankton, buoyancy-promoting gas vesicles in certain species, N-fixing capability of certain species, and the ability of certain species to extract P from the sediments directly.

While cyanobacteria-ecosystem dynamics are not yet fully understood in Pigeon Lake, ecological perturbations observed in other eutrophic lakes may indicate some of the potential impacts that cyanobacteria blooms have on Pigeon Lake's biota. For example, the increased turbidity of lake water during and following cyanobacteria blooms decreases light penetration into the water, which suppresses the growth of rooted aquatic vegetation. The capacity of the vegetation to uptake P from the sediments and retain it in biomass is reduced, resulting in more nutrients available for internal loading and feeding cyanobacteria blooms, thereby promoting a positive feedback cycle.

The water temperature of Pigeon Lake is another important factor affecting water quality, as cyanobacteria are known to have a competitive advantage over other phytoplankton in warmer waters. Water temperature varies both seasonally and diurnally, though the shallow basin in Pigeon Lake limits thermal stratification and results in largely consistent temperatures and dissolved oxygen levels throughout the water column.

Metals are naturally present in aquatic environments as an artifact of rock weathering, though elevated levels of certain metals may be indicative of industrial pollution. While 27 metals were detected in Pigeon Lake water column samples in 2003, 2012, and 2014-2017, all of these occurrences were well below their respective water quality guidelines.

Paleolimnological Sediments Studies

The water quality of Pigeon Lake has been well monitored within recent decades in response to the eutrophication and frequent cyanobacteria bloom events that currently affect the lake. However, the existing water quality data record do not cover large periods of Pigeon Lake's watershed development during the mid-20th century, resulting in limited data available to determine whether the lake water quality and algal dynamics baselines have changed over time.

In 2013, a paleolimnological study of Pigeon Lake was undertaken to examine changes in lake water quality over the past century (~1900-2013) using multiple indicators in lake sediments (Köster et al. 2014). Analysis of sediment cores revealed that Pigeon Lake is naturally rich in nutrients and cyanobacteria, with an enrichment of organic materials, P and cyanobacteria counts in the 1950s corresponding to watershed development. Over the entire study period, a slight increase in cyanobacteria abundance relative to other phytoplankton taxa was observed. Additionally, calmer waters and increased lake ion content within the past 20 years were inferred based on phytoplankton community data.

As Pigeon Lake is a naturally productive lake, a realistic water quality management target would be to maintain a water quality standard sufficient for normal recreational use with limited algae blooms. In other words, an acceptable water management target would be to lower nutrient concentrations to a point where the lake maintains excellent fish and wildlife productivity, but enough to reduce the frequency and intensity of algal blooms. As such, realistic expectations of watershed and water quality improvements are necessary. Cyanobacterial blooms are driven not only by watershed activities but also by water temperatures, wind and solar radiation, and internal nutrient loadings.

Food Web Studies

Manipulation of the relative abundances of organisms higher up in the food chain can be an effective approach to regulate cyanobacteria populations under certain conditions. One such approach is to increase the abundance of herbivorous zooplankton and thereby increase the amount of grazing pressure on the cyanobacteria. Researchers from the University of Alberta have begun to conduct such experiments in enclosed systems in Pigeon Lake. More research needs to be conducted to determine if a reduction in cyanobacteria levels in Pigeon Lake may be achieved through a top-down grazing approach before biomanipulation efforts can proceed.

Paleolimnological analysis of sediment cores indicates that cyanobacteria have been part of the phytoplankton community at Pigeon Lake for at least a century. However, favorable water conditions in recent years may have facilitated the excess proliferation of cyanobacteria into blooms. These conditions include not only excess nutrient (i.e., P) availability but also may include climate-related factors such as increased water column stability (due to altered wind patterns) and warmer surface water temperatures. While the exact mechanisms leading to bloom formation in Pigeon Lake are currently unknown, warmer and calmer waters likely give cyanobacteria a competitive advantage over true algae. Because these environmental conditions change seasonally and annually, however, prediction of cyanobacterial bloom occurrence, intensity, duration and location is difficult.

Due to its large size and shallow depth, the waters of Pigeon Lake are relatively well-mixed and thus well-oxygenated. Both dissolved oxygen levels and temperature are relatively consistent throughout the water column (albeit with seasonal variation), with anoxic conditions (dissolved oxygen concentrations < 2 mg/L) developing at depths of 7 m or deeper. As a by-product of photosynthesis, phytoplankton release oxygen into the water column, meaning that during a bloom there is typically an initial increase in the

dissolved oxygen content of the water column. However, when the colony of phytoplankton eventually dies, the decomposition of such a large quantity of biomass consumes much of the dissolved oxygen in the water column and may deplete the oxygen content of the water to critically low levels. Extensive asphyxiation and mortality of other aquatic life can occur, resulting in fish kills.

The fish populations of Pigeon Lake have been monitored for decades, though the precise interactions between cyanobacteria and the fish community are unknown. Dominance of the phytoplankton community by cyanobacteria may disrupt the balance in the natural food web structure of the lake, and thus affect the amount and quality of food for fish. Similarly, blooms may also cause environmental conditions unfavorable to fish health such water high in turbidity and low in oxygen.

In addition to these environmental stressors, fishes such as Walleye (*Sander vitreus*), Northern Pike (*Esox lucius*), Lake Whitefish (*Coregonus clupeaformis*), and Yellow Perch (*Perca flavescens*) have been subject to direct anthropogenic pressures such as habitat modification, angling, and commercial fishing. Despite being a large lake, Pigeon Lake is subject to greater fishing pressure than smaller lakes due to deeper areas of the lake being unusable as fish habitat. Consequently, both fish and anglers are concentrated into the small areas of suitable habitat. Any changes to the amount of available habitat or the existing angling rates will place more pressure on the fish populations and may contribute to a fishery collapse.

Overharvesting appears to have led to the extirpation of Walleye from Pigeon Lake in the 1950s, and the current sustainable population in the lake is the result of intensive stocking efforts in the 1990s. Lake Whitefish populations have fluctuated considerably over the past century but are currently considered to be stable. A large Lake Whitefish mortality event in 2012 was thought to be due to lake temperature but does not seem to have negatively affected overall populations. In Alberta the commercial fishery was ended in 2014. The Northern Pike populations in Pigeon Lake are considered collapsed, and a zero-catch limit was imposed as of April 1, 2016. Factors which may have contributed to this decline include the extirpation of this species in the 1950's, loss of littoral spawning and feeding habitat, direct competition with the reintroduction of Walleye as an apex predator, and overfishing. Similarly, Yellow Perch populations are considered to be in a vulnerable to collapsed state. All species are under threat from ongoing habitat loss and overfishing.

BMPs from Other Jurisdictions

The APLM technical committees have reviewed several methods that have been implemented in other jurisdictions to address excess lake nutrient levels and harmful algal blooms. Treatment options which may be feasible include:

- Short-term treatment options (removal of phytoplankton)
    - Biomanipulation to support top-down biological control of cyanobacteria
    - Harvesting phytoplankton from the water surface and shorelines and
- Longer term treatment options (inactivation of nutrients)
    - Chemical inactivation of P in the water column via addition of alum, calcium, iron or lanthanum-enriched bentonite clay (e.g., Phoslock®)

These approaches are currently being reviewed to determine their viability to treat the current water quality problems in Pigeon Lake; however, the circumstances supporting their efficacy at one lake may not be true when applied to another. Review of these strategies requires lake-specific research, environmental and socio-economic risk assessments (including evaluation of potential risks to the lake, financial costs, and overall efficacy), and formal stakeholder consultation and regulatory approval prior to implementation.

Plan Implications

- To maintain the natural functioning of an aquatic ecosystem adapted to nutrient-rich conditions, an appropriate management target would be to maintain a water quality level amenable for recreational use with a minimal occurrence of algae blooms.
- Pigeon Lake is naturally nutrient-rich, with the P loading into the water column from both the watershed and lake sediments. Thus, actions should be taken to reduce both external and internal nutrient loading into Pigeon Lake, though the allocation of efforts between these sources may vary due to technical, financial, and feasibility considerations. Development of a nutrient reduction model may be an effective approach to determine what combination of activities will result in the most effective remediation with a relatively low level of risk.
- The existing P budget for Pigeon Lake should be recalculated with the additional P data collected from the lake and inflowing streams, including the importance of the spring runoff (freshet), with updates to better reflect the true imports and export rates. For example, the current P budget does not account for biological sources of P, such as that in water-bird excrement or in the biomass of stocked fishes. In addition, the nutrient budget should consider the impact of bioavailable vs particulate P for source identification.
- In addition to increased nutrient availability, cyanobacteria blooms are likely driven by several additional factors such as increased water stability (both turbulence and thermodynamically), changing climate conditions, increased light availability, and shoreline modification. Further research is necessary to identify the interactions of these and other factors and to determine the mechanisms responsible for cyanobacteria bloom dynamics. For example, analysis of long-term water quality and phytoplankton community data may reveal the physical or chemical drivers behind seasonal phytoplankton community shifts favoring cyanobacteria dominance.
- A comprehensive water quality model should be developed for Pigeon Lake to assist with lake management. This could allow various management scenarios to be run and their effects on the lake ecosystem to be predicted, such anticipating potential trophic cascades or simulating the effects of supplemental water inputs on nutrient dynamics. Such a model would ideally incorporate all available hydrological, ecological, and water quality data for Pigeon Lake and its watershed to support informed decision-making.
- Accurate and up-to-date water quality data for Pigeon Lake are essential for updating the P budget and the development of an effective lake- and watershed-scale water quality model.
- Robust fish populations are important to both the ecology of Pigeon Lake and the sustainability of recreational and First Nations fisheries. Additional study of how fish populations interact with cyanobacterial blooms is warranted. Managing fish populations may provide a tool to assist in managing cyanobacterial blooms. In the meantime, a conservative fisheries management approach is recommended.

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APPENDIX D: GLOSSARY

Preface

This Glossary defines technical terms used in the Pigeon Lake Watershed Management Plan 2017 and Appendix C Technical Summary. These are technical terms which are in use by professionals for the management of Lakes and Watersheds in Alberta. Technical terms have been derived from two primary Alberta authorities. Environmental planning terms are derived largely from the latter GoA collection plus broadly sourced.

- Alberta Lake Management Society (ALMS): https://alms.ca/educational-resources/
- Government of Alberta: http://aep.alberta.ca/water/programs-and-services/water-for-life/partnerships/documents/8043.pdf

The reader is referred to the source authorities (above) for technical definitions not found below and for the definition source authorities.

Selected terms have been retained in this collection which are relevant to the Pigeon Lake Watershed Management Plan.

TECHNICAL TERMS – WATERSHED, LAKE MANAGEMENT & ENVIRONMENTAL PLANNING

Adaptive Management

A dynamic system or process of task organization and execution that recognizes the future cannot be predicted perfectly. Planning and organizational strategies are reviewed and modified frequently as better information becomes available. Adaptive management applies scientific principles and methods to improve management activities incrementally as decision-makers learn from experience, collect new scientific findings, and adapt to changing social expectations and demands. (SEM)

Algae

Aquatic, nonvascular organisms which typically contain chlorophyll and usually include the green, yellow-green, brown, and red algae and the blue-green algae (also known as cyanobacteria). (ALMS)

Algal Bloom

Population explosion of algae in surface waters due to an increase in plant nutrients such as nitrates and phosphates.[8] Usually due to excessive blue green algae growth. (ALMS)

Bacteria

Tiny, unicellular organisms that reproduce by cell division and usually have cell walls; can be shaped like spheres, rods or spirals and can be found in virtually any environment. (ALMS)

Beneficial Management Practices (BMPs)

Techniques and procedures that have been proven through research, testing, and use to be the most effective and appropriate for use in Alberta.

Effectiveness and appropriateness are determined by a combination of: (1) the efficiency of resource use, (2) the availability and evaluation of practical alternatives, (3) the creation of social, economic, and environmental benefits, and (5) the reduction of social, economic, and environmental negative impacts. (BRBC)

Benthic

Referring to bottom zones or bottom-dwelling forms. (ALMS)

Benthos

Animals and plants living on or within the substrate of a water body (freshwater, estuarine or marine). (ALMS)

Bioavailability

The amount of a nutrient that is in a form that is available for uptake and use by biological organisms. (ALMS)

Biodiversity

The existence of a wide range of different types of organisms in a given place at a given time. (ALMS)

Chlorophyll

A green, light-absorbing pigment found in plants and other photosynthetic organisms. A magnesium-porphyrin complex, it is an essential electron donor in photosynthesis. The amount of chlorophyll present in lake water depends on the amount of algae and is therefore used as a common indicator of water quality. (ALMS)

Clarity

A measure of the light penetration of water, generally measured using a Secchi disk. (ALMS)

Conservation

1. The planning, management, and implementation of an activity with the objective of protecting the essential physical, chemical, and biological characteristics of the environment against degradation. (EPEA)

2. The process of managing biological resources (e.g., timber, fish) to ensure replacement by re-growth or reproduction of the part harvested before another harvest occurs. A balance between economic growth and environmental and natural resource protection. (G&G glossary)

Cumulative Effects

The combined effects on the aquatic environment or human developments arising from the combined environmental impacts of several individual projects. (WCAG)

Cyanobacteria

A group of aquatic bacteria (also known as blue-green algae) that are capable of photosynthesis. Excessive amounts of cyanobacteria (harmful algal blooms) can negatively impact water quality through production of natural toxins (e.g., microcystin) and through depleting water oxygen levels. (ALMS)

Decomposition

The breakdown of dead organic material through physical, chemical and biological processes. (ALMS)

Detritus

Undissolved organic or inorganic matter resulting from the decomposition of biological parent material. (ALMS)

Dissolved Oxygen

The amount of free oxygen absorbed by the water and available to aquatic organisms for respiration; amount of oxygen dissolved in a certain amount of

water at a particular temperature and pressure, often expressed as a concentration in parts of oxygen per million parts of water (ppm). (ALMS)

Drainage Basin

The total area of land that contributes water and materials to a lake, river, or other water body, either through streams or by localized overland runoff along shorelines. (SWQG)

Diffuse Phosphorus Load

Diffuse is associated with particular land uses as opposed to individual points of origin or discharge. Diffuse phosphorus loading can arise from activities related to agriculture, forestry, urban development, mining, oil and gas, construction, and recreation. Such diverse sources along with the fact that diffuse sources can be transported by rainwater, snowmelt, runoff, air deposition and groundwater, make it difficult to prevent, measure, control, quantify and manage this type of pollution. Land surface (e.g., slope), soil texture, geology, vegetation, hydrology and climate also affect the timing and extent of Diffuse loads. (also known as non-point source pollution; also see pollution)

Ecosystem

A community of interdependent organisms together with the environment they inhabit and with which they interact. (BRBC)

Ecosystem Functions

Processes that are necessary for the self-maintenance of an Ecosystem such as primary production, nutrient cycling and decomposition. The term is used primarily as a distinction from values. (NALMS)

Environment

The components of the earth, including air, land, and water, all layers of the atmosphere, organic and inorganic matter, living organisms, and their interacting natural systems. (EPEA)

Environmental Indicator

A measurement, statistic or value that provides a proximate gauge or evidence of the effects of environmental management programs or of the state or condition of the environment. (NALMS)

Environmental Outcome

The desired environmental end state defining the specific conditions or functions that one expects for the environment. An outcome is an event, occurrence, or condition that results from an activity or program that has an actual effect on resources, the environment, or Albertans. (IHCR

Environmentally Significant Area (ESA)

ESA's are identified areas containing rare or unique elements in the province, or areas that include elements that may require special management consideration due to their conservation needs. ESAs do not represent government policy and are not necessarily areas that require legal protection, but instead are intended to be an information tool to help inform land use planning and policy at local, regional and provincial scales.

Erosion

Movement of soil by water or wind. (ALMS)

Eutrophic

Rich in dissolved nutrients, photosynthetically productive and often deficient in oxygen during warm weather. (ALMS)

Eutrophication

The process by which lakes and streams are enriched by nutrients, and the

resulting increase in plant and algae growth. This process includes physical, chemical, and biological changes that take place after a lake receives inputs for plant nutrients–mostly nitrates and phosphates–from natural erosion and runoff from the surrounding land basin. The extent to which this process has occurred is reflected in a lake's trophic classification: oligotrophic (nutrient poor), mesotrophic (moderately productive), and eutrophic (very productive and fertile). (ALMS)

Evapotranspiration

Loss of water by evaporation from the soil and transpiration from plants. (ALMS)

Exotic Species

Plant or animal species introduced into an area where they do not occur naturally; non-native species.1 Examples area Eurasian Milfoil and Purple Loosestrife. (ALMS)

Flushing Rate/Retention Time

Flushing rate is the rate of water replacement in a lake. Its unit of measure is times/year. Conversely, retention time is the average length of time water resides in a lake, ranging from several days in small impoundments to many years in large seepage lakes. Retention time is important in determining the impact of nutrient inputs. Long retention times result in recycling and greater nutrient retention in most lakes. Calculate retention time by dividing the lake volume by the volume of water passing through the lake in one year. (ALMS)

Food Chain

The transfer of food energy from plants through herbivores to carnivores. An example: insect-fish-bear or the sequence of algae being eaten by small aquatic animals (zooplankton) which in turn are eaten by small fish which are eaten by larger fish and eventually by people or predators. (ALMS)

Geographic Information Services (GIS)

A set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes.

Geospatial

Fusion of geography and information technology collection, management, analysis and integration of geo/location-based data to enable improved decision and policy making.

Geospatial Data

Data pertaining to the geographic location and characteristics of natural/constructed features and boundaries on, above, or below the Earth's surface.

Healthy Aquatic Ecosystem (Healthy Lake)

An aquatic environment that sustains its ecological structure, processes, functions, and resilience within its range of natural variability. Alberta Water Council. 2008

Hydrological Cycle

Refers to the processes by which water moves in the global environment. Includes condensation, precipitation, runoff, storage and evapotranspiration, and quantitatively measured using distribution and concentration. (ALMS)

Kjeldhal Nitrogen

The most common analysis run to determine the amount of organic nitrogen in water. The test includes ammonium and organic nitrogen. (ALMS)

Littoral

Pertaining to or along the shore, particularly to describe currents, deposits, and drift. (ALMS)

Macrophytes

A member of the rooted aquatic plant life of an area, especially of a body of water. Typically refers to emergent plants such as cattails and reeds. (ALMS)

Microcystin

A group of toxins naturally produced by certain species of cyanobacteria. Harmful to human, animal and ecological health in sufficient concentrations. (ALMS)

Morphometry

Measurement of external form.[7] Lake morphometry includes maximum and average depth, surface area, volume, shoreline length, basin shape, etc. (ALMS)

Nitrogen Fixation

The conversion of atmospheric nitrogen (N_2) into an organic form usable by plants and other organisms; nitrogen is typically fixed by bacteria that live in nodules on the roots of legumes and similar plants. (ALMS)

Nutrients

Elements or substances such as nitrogen and phosphorus that are necessary for plant growth. Large amounts of these substances can become a nuisance by promoting excessive aquatic plant growth. (ALMS)

Oligotrophic

Describes a body of water in which nutrients are in low supply. (ALMS)

Orthophosphorus

Dissolved inorganic phosphorus. The dissolved inorganic form of phosphorus that is immediately bio-available for absorption by algae. Also, can be referred to as soluble reactive phosphorus (SRP). Chemical formula is PO_4^{3-}.(ALMS)

Pathogen

A disease-producing agent; usually applied to a living organism. Generally, any viruses, bacteria, protozoans or fungi that cause disease. (ALMS)

Phosphorus

Key nutrient influencing plant growth. Soluble reactive phosphorus (orthophosphorus) is the amount of phosphorus in solution that is readily available or Bioavailable to plants. Total phosphorus includes the amount of phosphorus in solution (reactive) and in particulate form. (ALMS)

Photosynthesis

Process through which light energy, water, and carbon dioxide are converted to carbohydrate and oxygen in the presence of chlorophyll. Occurs in plants, algae, cyanobacteria and lichens. (ALMS)

Phytoplankton

Microscopic plants found in the water. Algae or one-celled (phytoplankton) or multicellular plants either suspended in water (plankton) or attached to rocks and other substrates (periphyton). Their abundance, as measured by the amount of chlorophyll a (green pigment) in an open water sample, is commonly used to classify the trophic status of a lake. Numerous species occur. Algae are an essential part of the lake ecosystem and provides the food base for most lake organisms, including fish. Phytoplankton populations vary widely from day to day, as life cycles are short. (ALMS)

Plankton

Small plant organisms (phytoplankton and nanoplankton) and animal organisms (zooplankton) that float or swim weakly though the water. (ALMS)

Point-Source Pollution or Non-Point Source Pollution

Pollution that originates from one, easily identifiable cause or location, such as a sewage treatment plant or feedlot. (WFL)

Pollutant

A contaminant in a concentration or amount that adversely alters the physical, chemical, or biological properties of the natural environment.

Pollution

Cumulative effect of a pollutant or combination of pollutants on the natural environment of a location or locations. Two types are:

- Point-Source Pollution: that originates from one, easily identifiable cause or location, such as a sewage treatment plant, outfall or feedlot.
- Non-Point Source Pollution: that enter a water body from diffuse or undefined sources and are usually carried by runoff. Examples of non-point sources include agricultural land, coal mines, construction sites, roads, and urban areas. Because non-point sources are diffuse, they are often difficult to identify or locate precisely, and are therefore difficult to control.

Restoration

Measures undertaken to return a degraded ecosystem's functions and values, including its hydrology, plant and animal communities, and/or portions thereof, to a less degraded ecological condition. (ALMS)

Riparian

Pertaining to the banks of a river, stream, waterway, or other, typically, flowing body of water as well as to plant and animal communities along such bodies of water. (NALMS)

Riparian lands are transitional areas between upland7 and aquatic ecosystems. They have variable width and extent above and below ground and perform various functions. These lands are influenced by and exert an influence on associated water bodies8, including alluvial aquifers9 and floodplains. Riparian lands usually have soil, biological, and other physical characteristics that reflect the influence of water and hydrological processes. Alberta Water Council

Residence Time

Length of time that water will remain in a lake or other water body.

Secchi Disk

A 20 cm (8 inch) diameter plate with alternating quadrants painted black and white that is used to measure water clarity (light penetration). The disc is lowered into water until it disappears from view. It is then raised until just visible. An average of the two depths, taken from the shaded side of the boat, is recorded as the Secchi disc reading. For best results, the readings should be taken on sunny, calm days. (ALMS)

Sedimentation

The process of or accumulation of sand and dirt settling on the bottom of a lake. (ALMS)

Shore

The edge of a body of water and includes the land adjacent to a body of water that has been covered so long by water as to wrest it from vegetation or as to mark a distinct character on the vegetation where it extends into the water or on the soil itself. (PSSSPH)

Stakeholder

An individual, organization, or government with a direct interest in a particular process or outcome. (SEM)

State of the Watershed Report

A document that identifies the current condition of a watershed including the physical, chemical, and biological characteristics of its surface and groundwater and the pressures acting on it. (Partnerships)

Stewardship

Stewardship

A principle or approach whereby citizens, industry, communities, and government work together as stewards of the province's natural resources and environment. In general terms, stewardship means managing one's life, property, resources, and environment with regard for the rights or interests of others. This can apply to a person, company, community, government or group. Stewardship is an ethic and a value that results from public education and partnerships. It is people-focused in the sense that it relies on the desire

and ability of people to make good decisions on their own accord that help resource and environmental outcomes. (SEM)

Stratification

The layering of water due to differences in density. Water's greatest density occurs at 4 °C (39 °F). As water warms during the summer, it remains near the surface while colder water remains near the bottom. Wind mixing determines the thickness of the warm surface water layer (epilimnion), which usually extends to a depth of about 6.5 m (20 feet). The narrow transition zone between the epilimnion and cold bottom water (hypolimnion) is called the metalimnion or thermocline. (ALMS)

Surface Water

Water bodies such as lakes, ponds, wetlands, rivers, and streams, as well as groundwater with a direct and immediate hydrological connection to surface water (for example, water in a well beside a river). (SSRB)

Suspended Solids

A measure of the particulate matter in a water sample, expressed in milligrams per liter. When measured on inflowing streams, it can be used to estimate the sedimentation rate of lakes or impoundments. (ALMS)

Sustainability

Development that meets the needs of the present without compromising the ability of future generations to meet their own needs. (UN)

The balancing of opportunities for growth with the need to protect the environment. It reflects a vision of a vibrant economy and a healthy environment. Regarding renewable resources (e.g.: water, timber, fish, and wildlife), sustainability involves managing renewable natural resources so that their status, condition, or use is maintained over time. In this context, the use of a renewable resource, or impacts on it from other human activities, should not exceed its capacity to maintain itself through re-growth, reproduction, and management practices. Regarding non-renewable resources (e.g.: coal, oil, gas, and minerals), sustainability involves the development of resources in a responsible manner. This means protecting the environment during the construction and operation phases and ultimately reclaiming the land disturbed by development. In this context, non-renewable resource development is a temporary land use. (SEM)

Transpiration

The passage of water in plants from the roots through the vascular system to the stoma of the leaves and into the atmosphere. (ALMS)

Trophic Levels

A classification of organisms according to what they eat and their relative position in the food chain (e.g., primary producers, herbivores, predators, decomposers). (ALMS)

Trophic State

Eutrophication is the process by which lakes are enriched with nutrients, increasing the production of rooted aquatic plants and algae. The extent to which this process has occurred is reflected in a lake's trophic classification or state: oligotrophic (nutrient poor), mesotrophic (moderately productive), and eutrophic (very productive and fertile). (ALMS)

Turbidity

Degree to which light is blocked in water because water is muddy or cloudy. (ALMS)

Upland

An area of dry land surrounding or upstream of a water body. (WCW)

Water Act

A piece of provincial legislation in Alberta used to protect the quality of water and manage its distribution. The Water Act regulates all developments and activities that might affect rivers, lakes, or groundwater. (WFL)

Water Body

Any location where water flows or is present, whether or not the flow or the presence of water is continuous, intermittent, or occurs only during a flood. This includes, but is not limited to, wetlands and aquifers. (WFL)

Water for Life: Alberta's Strategy for Sustainability

The Government of Alberta's water management approach, outlining a comprehensive set of strategies and actions that will ensure Albertans have safe, secure drinking water, healthy aquatic ecosystems, and a reliable quality water supply for a sustainable economy. (GWMT)

Water Management

The protection and conservation of water and aquatic ecosystems, including their associated riparian area. In Alberta, several agencies have a mandate in this area. Alberta Environment is responsible for water quality, quantity monitoring, and water allocations. Under the Water Act a Director can set Water Conservation Objectives to protect minimum flow and aquatic ecosystem health. Stakeholders can recommend Water Conservation Objectives to a Director via a Water Management Plan or an Approved Water Management Plan. Alberta Sustainable Resource Development (SRD) manages crown lands including the bed and shores of all water bodies. SRD, through its Fish and Wildlife Division, is also responsible for fisheries and wildlife management. In addition, the Federal Department of Fisheries and Oceans upholds a no-net-loss policy in its mandate to protect fisheries habitat under the Federal Fisheries Act. (Partnerships)

Water Quality

A term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose. (ALMS)

Water Quantity

The volume or amount of water. (FWMP)

Watercourse

The bed and shore of a river, stream, lake, creek, lagoon, swamp, marsh or other natural body of water, or a canal, ditch, reservoir or other artificial surface feature made by humans, whether it contains or conveys water continuously or intermittently. (EPEA)

Watershed

Watershed - An area of land, bounded by topographic features, that drains into a shared destination such as a river, stream, lake, pond or ocean. The size of a watershed can be tiny or immense and its boundaries and velocity of flow are determined by land forms such as hills, slopes and mountain ranges that direct water. Within each large watershed, there are many smaller watersheds.

Watershed Approach - Place-Based Approach

A way of thinking and acting that focuses efforts within a watershed, taking into consideration both ground and surface water flow. This approach recognizes and plans for the interaction of land, water, plants, animals, and people. Focusing efforts at the watershed level gives the local watershed community a comprehensive understanding of local management needs and encourages locally led management decisions. (WFL)

Watershed Management / Water Management

The protection and conservation of water and aquatic ecosystems, including their associated riparian area. Because land use activities on the uplands of a watershed can affect ground and surface water quality and quantity, a

broader, more comprehensive approach to planning is often required. A Watershed Management Plan may look at water quantity, water quality, aquatic ecosystems, riparian area, as well as a variety of land use issues as they impact water. Watershed management plans require water and land use managers to work together to ensure healthy watersheds. (Partnerships)

Watershed Management Plan Water Management Plan

A comprehensive document that addresses many issues in a watershed including water quantity, water quality, point and non-point-source pollution, and source water protection. It may or may not include a Water Management Plan. It may also examine ways to better integrate land and resource management within a watershed. (Partnerships)

Watershed Management Planning /Watershed Management Plan

A comprehensive, multi-resource management planning process involving all stakeholders within the watershed, who, together as a group, cooperatively work toward identifying the watershed's resource issues and concerns as well as develop and implement a watershed plan with solutions that are environmentally, socially and economically sustainable. (NSWA)

Watershed Planning and Advisory Council (WPAC)

Collaborative, independent, volunteer organizations with representation from all key partners within the watershed. Their mandate is to engage governments, stakeholders, other partnerships, and the public in watershed assessment and watershed management planning, while considering the existing land and resource management planning processes and decision-making authorities. (Partnerships)

Watershed Stewardship Group (WSG)

Community-based groups made up of volunteer citizens, often supported by local businesses and industries, who have taken the initiative to protect their local creek, stream, stretch of river, or lake. These proactive groups develop on-the-ground solutions to ensure the protection of their specific watersheds. (WFL)

Wetland

Land that is saturated with water long enough to promote wetland or aquatic processes as indicated by poorly drained soils, water-loving vegetation, and various kinds of biological activity which are adapted to a wet environment.

Zooplankton

A community of floating, aquatic, minute animals and non-photosynthetic protists. (ALMS)

GENERAL PLANNING TERMS

Collaboration

A process through which parties that see different aspects of a problem can explore constructively their differences and search for (and implement) solutions that go beyond their own limited vision of what is possible. Collaboration is a mechanism for leveraging resources; dealing with scarcities; eliminating duplication; capitalizing on individual strengths; building internal capacities; and increasing participation and ownership strengthened by the potential for synergy and greater impact.

Intermunicipal Dispute

A municipality holding the opinion that a statutory plan, land use bylaw or amendment adopted by an adjacent municipality will have a detrimental effect on it.

Dispute Resolution

The process to inform and negotiate a mutually beneficial resolution of a defined intermunicipal dispute. If a mutually beneficial negotiation cannot be achieved the municipalities can seek a resolution through mediation and, ultimately through an appeal to the Municipal Government Board.

Framework

An organized structure of policies, legislation, programs and tasks created to achieve a specific outcome. There can be frameworks for broad policies and strategic initiatives at various scales (e.g. provincial, regional, sector, media); programs and program delivery; and short-term tasks and projects. (SEM)

Growth

Growth of a region or municipality is defined as increase in its size, population or employment.

Governance

The process of decision-making and the process by which these decisions are implemented.

Guideline

A specific performance measure that is not legally binding unless designated in legislation. It is a guide or indication of a future course of action. It describes how something will be accomplished. It may contain numerical performance measures and may deal with multiple uses of water.

Objective

The result of either planned or unplanned actions. For planning purposes, "objectives" are the desired endpoint and should guide the development and implementation of related programs. Outcomes can be broad and long-term in nature or focused. They are used in both direction setting and performance measurement.

Partnership

A relationship in which individuals or organizations share resources and responsibility to achieve a common objective, as well as any resulting rewards or recognition. It often includes a formal contract, new resources and shared risks and rewards. The structure includes a central body of decision-makers whose roles are defined. The links are formalized. Communication is frequent, the leadership is autonomous, and the focus is on specific issues. Partnerships are a form of collaboration.

Methods

The methods are formal agreements between organizations that are sharing people, technology, process or data and explain how the item is being shared and sets out the means and systems CRGIS will adopt when they collect, store, access, compile and analyze information about the region

Policy

1. A governing principle, plan, or consistent course of action developed in order to meet recognized needs and to achieve specific measurable outcomes. Policies are normally broad, conceptual documents that outline approaches and/or considerations to be taken into account by decision makers. Policies do not act as constraints, but provide information. (SEM)

2. A statement of intent that is not legally binding. It sets direction and expectations for activities.

Provincial Land Use Framework

A policy of the Government of Alberta to introduce and implement regional land use plans to ensure the long-term health of Alberta's communities, economy and the environment.

Public and Stakeholder Involvement

The process used to obtain advice or recommendations from a community and engage them in decision-making. Public and stakeholder involvement is an umbrella term that includes a range of interactive approaches including information and education, consultation, collaboration, partnerships, and delegated authority.

Referral

Involves informing adjacent jurisdictions of new or amended plans, land use bylaws or new development proposals providing opportunity to comment on how the proposal may impact them.

Recreation Corridor

Inter-connected crown, public or private lands that are generally linear in form and are of regional significance for the purpose of providing recreational opportunities, such as the Trans Canada Trail, walking trails and parks and open space in the North Saskatchewan River Valley. Regional Recreation Corridors may also provide access to municipal recreation opportunities.

Region

Region, specifically the geographic area contained within the participating jurisdictions.

Regional

Relating to the Region, whether by geographic proximity or by the impact that actions or decision may have on others.

Stakeholder

An individual, organization, or government with a direct interest in a particular process or outcome.

Strategy / Strategic

A perspective, position, or plan developed and undertaken to achieve goals. It is the bridge between policy and concrete actions that outlines how a policy will be implemented to achieve its goals. (SEM)

MUNICIPAL AND REGIONAL PLANNING TERMS

Area Structure Plan (ASP)

A statutory plan identifying many neighbourhoods where residential, commercial, institutional and recreational areas will be located in a previously undeveloped area. These plans also describe the number of people expected to live in the new area and how development will be staged over time.

Development

A change in the use or intensity of use of land or a building or an act done in relation to land or a building that results in or is likely to result in a change in the intensity of use of land or building.

Intermunicipal Development Plan (IDP)

A statutory plan containing broad-based policies that are prepared by two or more neighbouring municipalities. Their main purpose is to ensure that future growth reflects the mutual and individual interests of the municipalities involved. Typically, the focus is on the boundary area between rural and urban municipalities.

Land Use Bylaw (LUB)

A Bylaw that divides a municipality into land use districts and establishes procedures for processing and deciding upon development applications. It sets out rules that affect how each parcel of land in a municipality may be used and developed.

Liveability / Quality of Life

The environmental and social quality of an area as perceived by residents, employees, customers and visitors. This includes safety and health (traffic safety, personal security, and public health), local environmental conditions (cleanliness, noise, dust, air quality, and water quality), the quality of social interactions (neighbourliness, fairness, respect, community identity and pride), opportunities for recreation and entertainment, aesthetics, and existence of unique cultural and environmental resources (e.g. historic structures, mature trees, traditional architectural styles).

Low Impact Development (LID)

A land planning and engineering design approach for managing stormwater runoff. LID emphasizes conservation and use of on-site natural features to protect water quality. This approach implements engineered small scale hydrologic controls to replicate the predevelopment hydrologic regime of watersheds through infiltrating, storing, evaporating, and detaining runoff close to its source.

Municipal Development Plan (MDP)

A statutory plan that functions as a municipality's overall policy guide for future growth and development. The Plan outlines the direction of future development, the provision of transportation systems and municipal services, the coordination of municipal services and programs, environmental matters and economic development.

Municipal Government Act (MGA)

The primary provincial legislation that governs municipalities is known as the Municipal Government Act or MGA. The MGA sets out legislated roles and responsibilities of municipalities and municipal officials.

Municipal Reserve (MR)

Lands designated as "Municipal Reserve" are lands for schools, parks and public recreation purposes provided by the developer as part of the subdivision process.

Non-statutory Plan

A plan adopted by a municipality by resolution to address land use planning or master planning needs.

Redevelopment

The creation of new units, uses or lots on previously developed land in existing urban communities, including brownfield sites.

Statutory Plan

A plan approved by a municipality under the authority of the Municipal Government Act (MGA) with the passage of a municipal bylaw. Examples of a statutory plan are: an inter-municipal development plan, a municipal development plan (MDP), area structure plans (ASP), neighbourhood structure plan (NSP) and area redevelopment plans (ARP).

Social Infrastructure

Social infrastructure, or soft infrastructure, can refer to services provided by or in municipalities such as hospitals, community and recreational facilities, public spaces, social housing, volunteer networks and community-based agencies.

INFRASTRUCTURE TERMS

Infrastructure

Physical assets to provide services to citizens and to support the functioning of a local or regional economy, including roads, sewer lines, transit, emergency response vehicles, recreational facilities, parks, information technology and more.

Infrastructure, Local

Infrastructure that has capital investment and maintenance requirements, including roadways, sidewalks, street lights and traffic signals, transit facilities, solid waste and water delivery systems, potable water distribution systems, storm sewers, sanitary sewers, sports fields, playgrounds, arenas, pools, police and emergency stations, civic buildings and parks to support the concept of complete communities.

Infrastructure, Regional

Infrastructure developed by the federal government, Province, municipality, and/or regional service and provincial commissions to provide services to citizens and businesses, and to support the function of a regional economy (e.g. major interchanges, post-secondary institutions, hospitals, bridges, highways, extension of light rail transit, regional water and/or sewer systems, power systems).

Utilities - Franchised

Facilities for gas, electricity, telephone, cable television, water, storm and sanitary sewer.

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