

Pigeon Lake Watershed Management Plan

This management plan has been adopted by the municipalities listed below, whose councils have each passed the following resolution:

Council, having read and considered the Pigeon Lake Management Plan, resolves as follows:

1. to refer proposed major developments within [the municipality] to other municipalities as set out in the plan,
2. to consider the effect on the lake as a whole, and on other municipalities around the lake, before approving any development in the Pigeon Lake watershed, and
3. to use the policies set out in the Management Plan as a guide when making any decision affecting the Pigeon Lake watershed.

Municipality	Date of adoption
Leduc County	11 January 2000
County of Wetaskiwin	08 February 2000
SV of Argentia Beach	29 February 2000
SV of Crystal Springs	15 April 2000
SV of Grandview	22 March 2000
SV of Golden Days	14 March 2000
SV of Itaska Beach	16 March 2000
SV of Ma-Me-O Beach	18 April 2000
SV of Norris Beach	14 March 2000
SV of Poplar Bay	20 April 2000
SV of Silver Beach	04 May 2000
SV of Sundance Beach	23 March 2000

PART ONE: TECHNICAL BACKGROUND

In the spring of 1997, the two counties and ten summer villages bordering Pigeon Lake, organized as the Association of Pigeon Lake Municipalities (APLM), agreed to fund a study of lake water quality. The purpose was to find out if increasing onshore development had resulted in changes to water quality since the previous 1983 study by Hardy Associates, and how development in the drainage basin should be handled to preserve the recreational value of the lake.

The work was contracted to Lilley Environmental Consulting in conjunction with Dr Chris Earle of Concordia College in Edmonton. John Lilley is an independent environmental consultant. Chris Earle is an academic specializing in lake waters, and is active in the Alberta Lake Management Society. Their findings can be summarized as follows.

In a recreational lake, water quality is usually defined as (a) safe levels of pathogens and (b) clear water with minimal algae and plant growth (although too low a level will reduce fish populations).

Pathogens are minimized by proper sewage disposal systems. In general they are within acceptable limits at Pigeon Lake. Keeping them low is chiefly a public health education and enforcement issue, not a land use issue, although livestock can contribute through manure.

The limiting factor on plant growth in any lake is the supply of available nutrients in lake water. Although many nutrients are required for plant growth, phosphorus (chemical symbol P) is the limiting factor in most Alberta lakes.

Phosphorus may enter the water from various sources: atmospheric deposition, release from bottom sediments, or runoff from the land through streams or groundwater.

Atmospheric deposition is mostly uncontrollable but it is reduced if nearby land is covered in vegetation, which prevents wind erosion of the soil.

A large proportion of airborne phosphorus is in a form that is not usable for plant growth, so this source is less important than it might appear.

Release from bottom sediments depends largely on the dissolved oxygen content of the water at the bottom of the lake. If the water is full of dissolved oxygen, the phosphorus takes an oxidized form which is not available for plant growth. Mixing of the water (by boat traffic and other means) may also increase available phosphorus.

The study by Chris Earle and John Lilley shows that **the quality of the water of Pigeon Lake has not changed significantly over the past fifteen years.** The gains from the north-east

sewer system have likely more than offset losses from the conversion of forest land to agriculture. The consultants estimate that the north-east system may have reduced phosphorus input by anything from 70 kg to 640 kg a year, depending on the efficiency of the old systems which have been replaced. As the conversion of forest to farm land increases phosphorus runoff by about 40 kg/ha/yr, the higher figure would offset the conversion of 16 km² (about 25 quarter sections) from forest to agriculture. Air photos show that the loss has been far less than this.

Large quantities of available phosphorus can be released very quickly if the lake water becomes anoxic (oxygen-depleted). It could happen like this: increased phosphorus levels in the water, the result of nutrient-rich runoff, cause a burst of plant growth. When the plants die, their decomposition depletes the dissolved oxygen (DO) in the water. This changes the oxidized phosphorus in the bottom sediments into a non-oxidized ('reduced') form usable by plants, further increasing available nutrients for next year's plant growth. A positive feedback loop is established, locking the lake into a high nutrient, low oxygen state.

The amounts of phosphorus entering the lake from the land depends mainly on the use of land in the watershed. Forested land contributes only about 10 kg/km²/year. Farm land contributes 20 to 50 kg/km²/yr: less from hay land and more from crop. Urban areas contribute about 100 kg/km²/yr from surface runoff plus 0.1 to 0.9 kg per person depending on how sewage is treated.

In summary, the main risks to water quality are:

- o Increases in phosphorus will cause increases in aquatic plant growth. The most likely cause of increased phosphorus is the conversion of forest land to agriculture, especially livestock operations. Residential development also has an effect, but a small one.
- o As private sewage systems age, they could lose effectiveness, resulting in more fecal coliforms and plant nutrients reaching the lake.
- o Aquatic plant production could increase dramatically through positive feedback if available phosphorus reaches a critical level, but we do not know what that level is.

PART TWO: POLICY

The Association of Pigeon Lake Municipalities appointed a committee to review the consultants' report and to come up with recommendations for action by the municipalities. The committee consisted of:

Oren Hutton, Grandview, representing south side summer villages;
Leon Maryka, County of Leduc;
Doreen Purcell, Golden Days, representing north side summer villages;
Nancy Watson, County of Wetaskiwin;
Bob Riddett, West Central Planning Agency.

Ruth Harrison replaced Leon Maryka after he retired in October 1998.

The committee used the consultants' report to prepare recommendations for the management of land in the Pigeon Lake drainage basin. The committee drew the following conclusions from the report:

- o We should try to stabilize the input of phosphorus into the lake at present levels.
- o Atmospheric input and bottom-release are uncontrollable. Only land-based input is controllable.
- o The easiest way to stabilize phosphorus input is to freeze the level of development (residential, recreational and agricultural) in the watershed, but this is both politically impossible (farmers suffer to benefit cottage owners) and unnecessary because there are other ways of minimizing nutrient input.

The committee also considered issues of public access to the lake, the planning process, and other items of municipal concern. The committee has prepared this Watershed Management Plan for Pigeon Lake, and submits it for the consideration of the twelve lake shore municipalities.

Policies for Future Development in the Pigeon Lake Watershed

The Management Committee recommends that all development proposals in the Pigeon Lake drainage basin be judged according to the following principles:

1. Recognize the rights of the farming community.
2. Maintain water quality
3. Protect groundwater flows
4. Maintain public access to the lake
5. Protect the fishery
6. Allow suitable new development
7. Keep open communication on development proposals

The Committee also discussed three other issues:

8. Safe management of the water surface (boating regulations)
9. Co-operation on infrastructure
10. The summer village system

but decided that these were outside its terms of reference.

The seven principles and their implications for development are addressed in detail in the following pages.

POLICY 1: RECOGNIZE THE RIGHTS OF THE FARMING COMMUNITY

The Management Committee recognizes that farming in this area pre-dates the recreational use of the lake.

The report by John Lilley and Chris Earle shows that agriculture has a significant effect on water quality. Land clearance results in more runoff and less groundwater, and gives more fluctuations in streamflow. Runoff from farm land is richer in nutrients than from tree covered land, resulting in more plant and algae growth in the lake. However, agriculture is the backbone of the economy in the Counties of Leduc and Wetaskiwin, and the county councils will not demand any changes in accepted farming practices. Any desired changes must be achieved by education and incentive, not compulsion.

POLICY 2: MAINTAIN WATER QUALITY

The Management Committee believes that maintaining water quality must have the highest priority in lake and watershed management.

The consultant's report shows that the quality of the water in Pigeon Lake has not declined over the past fifteen years, but future water quality cannot be taken for granted. The biggest threat to water quality is from increasing the input of nutrients which stimulate the growth of algae and water plants.

The following measures can be used to reduce future nutrient input:

Ensure that private sewer systems are functioning properly: The first step is to determine the facts. How many substandard systems are there? Municipalities should jointly hire a summer student with public health training to examine existing systems and point out deficiencies to their owners.

Many cottage owners do not know how to maintain their sewage disposal systems. Municipalities should ask the health authorities for how-to manuals which can be sent to all property owners.

Eliminate grey water systems: Some older properties run bathroom waste through a septic tank and disposal field but allow grey water to flow out untreated. This treats pathogens but does nothing to remove the nutrients, especially phosphorus, which stimulate plant and algae growth in the lake.

Municipalities should work with the plumbing authorities and their safety codes inspectors to have these grey water systems brought up to code.

Work towards a municipal sewer system: Ideally, all lake cottages would be served by municipal sewer systems which collect waste water, pipe it to a lagoon, and release the treated effluent downstream from Pigeon Lake.

The north-east side of the lake has been served by such a system for several years. A similar system for the south side of the lake should be a long term goal, but it will be impossible without government funding like that given to the north-east. However, this need not prevent preliminary design and planning going ahead immediately.

The Provincial Park and the Indian Reserve should be invited to join this intermunicipal effort.

The first stage is to obtain land for a sewage treatment lagoon. This location must be technically feasible, affordable, and above all acceptable to nearby landowners. Local landowners must be involved from the start in any search for a lagoon site.

Eliminate the use of lawn fertilizer on lakeshore property: Lawn fertilizer is high in phosphorus and runoff into the lake can stimulate the growth of algae and water plants. Municipalities should start an education program to point out the deleterious effects when fertilizer leaches into the lake. Most people will react positively.

Examine the effect of golf courses: Golf courses are valuable addition to a cottage area, but there are concerns about high usage of fertilizers. Runoff may add large quantities of nutrients to the lake. This is of most concern when the golf course is close to the lake or a watercourse. Developers should provide a nutrient budget, prepared by a professional agrologist, as part of their development application.

Review existing animal operations: There are several intensive animal operations in the Pigeon Lake drainage basin. We do not know how well they are being managed at present. Although all existing farm operations are grandfathered under Policy 1, the operators would probably welcome an offer of help to improve their manure handling methods. County agricultural service board personnel should be made available to help them. The County of Wetaskiwin recently did this with a cattle operation near Coal Lake, with positive results.

Improving manure storage and handling systems could be costly, but there may be funds available from the Alberta government. Alberta Agriculture's Environmentally Sustainable Agriculture (ESA) program provides technical advice and some funding. Municipalities may wish to contribute financially to cleaning up a source of pollution, even if it is located in another municipality. Where there is a definite local benefit, local improvement levies might be used as the source of funds.

Control new animal operations: Alberta Agriculture provides technical support at no cost to municipalities and will advise whether a site is suitable from an environmental point of view. Among other things the department looks at manure handling and runoff.

It is possible to design and run an intensive animal operation so as to contain all nutrients on site. The critical factors are runoff from the confinement area, and how the manure is spread on the land. The counties should amend their land use bylaws so that all new confined animal operations (including cow-calf confinement areas) require a development permit, and then, as a condition of giving a permit, have operators design a system with minimal offsite effects.

Municipalities do not have the technical expertise to set operational standards for intensive animal operations. At present they depend on Alberta Agriculture to recommend standards.

The department is currently reviewing its rules and practices on intensive livestock operations. The latest discussion draft of the *Proposed Regulatory Framework for Livestock Feeding Operations in Alberta* says that

The province will set environmental siting requirements, construction standards, and the standards for manure storage and use. Municipal governments will retain responsibility for determining whether a proposed development is acceptable through the municipal planning process.

Some municipalities in Alberta are protecting recreational lakes by refusing to allow any new intensive livestock operations on land draining into those lakes. The County of Ponoka has done this in the Gull Lake basin, with surprisingly little opposition, even from the farm community. Leduc and Wetaskiwin should consider a similar policy, at least within a mile of the lake. Such a policy, being as land use and not an operational matter, appears to be compatible with the proposed provincial Regulatory Framework.

Consider the effect of new residential subdivision: Residences contribute nutrients to the lake if they are not on a piped sewer system, and this issue should be addressed in any Area Structure Plan for a new subdivision. (See Policy 6 below)

Preserve tree cover: Forested land contributes less nutrients per unit area than cleared land. Municipalities can provide incentives for landowners to maintain tree cover. This does not mean financial incentives; experience around Battle Lake shows that allowing subdivision is a very effective way of maintaining tree cover.

Figures obtained from Alberta Agriculture and the consultants show that the production of phosphorus is about the same from low intensity cow-calf farming and from human settlement at about three houses per acre (see technical note attached). Nevertheless, the management committee recommends a much lower density because of other constraints such as water supply and the effect on runoff patterns when more land is cleared. Lots in the three to five acre range certainly have less effect on lake water quality than if the same land was cleared and farmed. Where site conditions are suitable, development at this density should be encouraged on tree covered land in the first mile back from the lake shore. (This policy has been in effect in the County of Wetaskiwin for many years. Initially it resulted in an over-supply of lots, but most of that inventory has now been absorbed and we are seeing new subdivision applications.)

Further back from the shoreline, parcels of 20 acres should be allowed on tree covered land. The County of Wetaskiwin has done this since 1974 in the Battle Lake area. Comparison of 1973 and 1993 air photos reveals that this policy has been an outstanding success in retaining tree cover.

Actively monitor the lake: Municipalities and the public need to understand good lake management practice, know what can damage water quality, and know where to report threats to water quality. A handout should be prepared by Health, Environment, and Plumbing Inspection Branch staff, explaining the issues, giving addresses and telephone numbers for enquiries and complaints, and setting out the enforcement action open to government agencies, municipalities, and individuals. This handout should be available at municipal offices and could be included with the newsletters that some municipalities send out each year.

Enforce anti-pollution rules: In some cases, a probable pollution offence has been reported to a government agency, and no action has resulted. In other cases, the fines are so small that they can almost be seen as a licence to pollute. The twelve lakeshore municipalities should document such cases, and work through the municipal associations (AAMD&C and the summer villages' association) to have fines and penalties increased.

POLICY 3: PROTECT GROUNDWATER FLOWS

There is no municipal water system in the Pigeon Lake area, and no likelihood of one being set up, so it is essential to protect the supply of groundwater for domestic and farm use.

Alberta Environmental Protection demands proof of sustainable yield before issuing licences for large-scale users, but no licences are required for domestic wells. However, municipalities have the power to regulate future demand through their role as subdivision approving authorities.

Require proof of water supply: Before approving any subdivision which would create six or more lots in a quarter section, municipalities should require proof of adequate sustainable water supply from groundwater. This proof should take the form of a pump and recovery test undertaken by a qualified hydrogeologist, using methods acceptable to Alberta Environmental Protection. (This policy would only apply when groundwater is proposed to be used. It would not apply when water is to be trucked in and stored in cisterns, as is allowed in Leduc County.)

Note: since this document was drafted, a new Water Act has been enacted. Section 23 of the Act requires that a developer proposing to create six or more lots on a quarter section must submit, with the application, a letter from a qualified engineer, geologist, or geophysicist, stating that a diversion of 1,250 cubic metres of water per year for every household in the subdivision will not interfere with existing households, licensees, or traditional agricultural users. 1,250 cubic metres per year is about half a gallon per minute.

Recharge the aquifers: Areas of low, wet land often serve as groundwater recharge areas. When land is being subdivided, these recharge areas should normally be taken into municipal ownership as environmental reserve. Alternatively, they might be subject to environmental or conservation easements to limit land clearance or drainage.

Do not misuse potable groundwater: Municipalities should oppose the use of near-surface potable groundwater for deep injection or other oilfield uses. Applications for such uses are advertised in the local newspapers. County and Planning Agency staff should monitor the local papers and alert their councils to any proposals.

POLICY 4: MAINTAIN PUBLIC ACCESS TO THE LAKE

The Management Committee believes that Pigeon Lake is a public resource, and reasonable public access must be maintained.

Public access for is for all: Public reserves are for the use of all people, not just local residents. Restrictions such as unreasonable parking controls should be reviewed.

Maintain reserves: Lakeshore reserves should not be closed or made inaccessible to the public. This does not mean the public should have unrestricted access. Municipalities have the right and the duty to regulate the use of park areas for public safety, and to control nuisances.

Limit municipal liability: Some municipalities discourage the use of reserves, or try to close and sell them, because they are concerned about liability if a user is injured. This concern would disappear if the MGA was amended to limit municipal liability to cases of gross negligence in the operation of parks and reserves. The wording of section 531(1) (snow removal) might act as a model. This issue should be taken up with the government through the AAMD&C and the AUMA.

Convert roads to reserves: Because it is difficult to control the use of roads, municipalities may choose to convert roads into reserve lots under sections 22 and 665 of the Municipal Government Act. Golden Days has started to do this. In order to assure people that the land will still be available for public access, the village intends to convert roads to Environmental Reserve, because once land is so designated, it must be used only for natural and park purposes and can never be sold (sections 671 and 676 MGA).

Ensure access for back lot cottagers: It is irresponsible to create new cottage lots which have no lake access. New lots should be allowed only if they have safe, usable, legal access to

the lake. Lake access must be addressed in any Area Structure Plan for a proposed development.

Each back lot cottage (lots under one acre, within 400 metres of the lake) should have the use of at least ten feet of reserve frontage for lake access. This standard was developed in the 1970s, has worked well, and should not be abandoned.

The requirement for lake access should not apply to larger lots because experience shows that these landowners do not use the lake as much as people on smaller properties.

Have developers contribute to lake access: Developers often agree to provide or improve lake access which will benefit their subdivision. Where a proposed development is in the county, but will rely on lake access through a summer village, the county should bring the summer village into these negotiations.

Provide alternative access: Even though municipal reserves are intended for everyone, it is a fact that they are too small to accommodate big crowds. The bulk of public access to Pigeon Lake must be through the provincial parks. These parks should be developed to the fullest possible extent.

POLICY 5: PROTECT THE FISHERY

The Management Committee recognizes the importance of the sport and commercial fishery in Pigeon Lake.

A comprehensive report on the Pigeon Lake fishery, published in 1994 by Alberta Environmental Protection, concluded that the decline in lake whitefish, walleye, and northern pike was due to two factors: heavy fishing pressure (commercial and sport) and loss of habitat.

Fisheries management is a provincial responsibility, and municipalities are not part of the decision making process on stocking, catch limits, seasons, or other management issues. Nevertheless the municipalities can contribute to a healthy fishery.

Protect Fish Habitat: The health of the fishery depends on the offshore spawning and feeding areas. Along most of the lake the underwater vegetation is under constant attack by cottage

owners; only the undeveloped shoreline has significant fish habitat. Proposals to develop these areas must take into account the need to preserve offshore rooted vegetation.

Municipalities should seek the advice of Alberta Environmental Protection's fisheries biologists on all major shoreline subdivision and development proposals, and should consider the effects on fish habitat before approving any changes to land use. Local fish and game associations may also provide useful information.

POLICY 6: ALLOW PROPERLY PLANNED NEW DEVELOPMENT

The Management Committee believes that new subdivision and development can be allowed, provided that issues of water quality and lake access are addressed.

No master plan: The Management Committee rejects the concept of a single master plan setting out the location and type of future development in the Pigeon Lake area. Comprehensive master plans have a way of being overtaken by changing markets and technology. Instead, the Committee recommends that future development in the drainage basin be managed through Area Structure Plans prepared under section 633 of the MGA, using the principles set out in this document. These plans would cover quarter or half sections, and would be required before any multi-lot subdivision or major development was approved.

Joint preparation of Area Structure Plans: Area Structure Plans would be prepared and legally adopted by the municipality in which the land lies, giving that municipality ultimate control, but nearby municipalities must be involved in writing the plan. Neighbouring landowners must also have input. The rights of adjacent municipalities and landowners are guaranteed by section 636 of the MGA, but note that the right to be informed and consulted does not imply a right of veto.

Area structure plans should not be required for the construction of single dwellings, or simple subdivisions such as farmsite separations or splitting a title physically divided by a road or creek. Agricultural development should also be exempt, unless it is an intensive livestock operation.

Content of Area Structure Plans: Area Structure Plans commonly address all the standard development issues such as site conditions, road access, and utility services. In the Pigeon Lake area, they must also address impacts on lake access, water quality, and the costs imposed on adjacent municipalities and how these should be recovered from the developer. Developers may also propose pollution trading schemes whereby they offset the nutrient production from their development by reducing nutrient production elsewhere in the drainage basin.

Road Access: Any new, large scale subdivision or development should have road access directly off main county roads, instead of using lakeshore roads. An example of good design is Beachside Estates at Viola Beach. Residents can walk to the beach across reserve land, but they do not use the lakeshore road for vehicle access.

POLICY 7: KEEP OPEN COMMUNICATION ON SUBDIVISION AND DEVELOPMENT PROPOSALS

The Management Committee believes that municipalities should share information and jointly plan development.

Subdivision and development referrals: The joint preparation of Area Structure Plans will allow the summer villages to participate in long-term planning on their fringes, and will allow them to bring their concerns (traffic, use of lake access points, etc) to the attention of the counties at an early stage. There must also be a referral process for smaller scale developments which do not require an ASP.

The municipalities should agree to refer the following planning and development matters for each other's review and comment:

- o all applications to amend a municipal development plan, area structure plan, or land use bylaw relating to land within the drainage basin;
- o all subdivision applications within one mile of another municipality; and
- o all development permit applications for discretionary uses within one mile of another municipality.

These referrals must allow three weeks for response, unless the municipalities agree to a different time.

(Note: the wording of this section is based on the Intermunicipal Development Plan recently agreed between the City and County of Leduc.)

Effect of referrals: Municipalities should agree not to approve a subdivision or development within a mile of another municipality if it would genuinely harm the interests of the other municipality, for example by

- o imposing significant capital or operating costs on the other municipality, or

- o greatly increasing traffic on a road in the other municipality, or
- o depleting water supplies, or
- o contributing to flooding, or
- o channelling too many people through undersized or undeveloped lake access points.

Participation in development agreements: Sections 650 and 655 of the MGA allow a municipality to enter into an agreement with a developer covering such things as roads, drainage, and servicing. These agreements are often used to recover municipal costs arising from the development, such as offsite roads.

A subdivision or development in one municipality may cause costs to another municipality. In this case the second municipality should be invited to submit its recommendations to the municipality having jurisdiction. This will ensure that *bona fide* offsite costs falling on to the second municipality can be addressed in the development agreement.

PART THREE: IMPLEMENTATION

Policies have no value unless they are put into force. The committee looked at two ways of doing this.

The first option is to adopt this document as an intermunicipal development plan (IDP) under section 631 of the Municipal Government Act. This is a very powerful tool because every land use decision in the defined area (in this case the Pigeon Lake drainage basin) must comply with the plan.

The second option is to adopt the document more informally as a simple intermunicipal agreement, relying on the good faith of the participants to make it work. Signatories commit themselves to using it as a basis for deciding on subdivision and development proposals, but they do not have any legal obligation.

Both methods have been used. Leduc County has signed IDPs with the Beaumont and the City of Leduc, as have the City and County of Wetaskiwin, while the Town and County of Ponoka have used the more informal approach.

When councils are giving up autonomy, as they must with an IDP, they look for written guarantees that their interests will not be ignored. Discussions over detailed wording can go on for months even when there are just two municipalities involved. The committee believes it will be impossible to get twelve councils to reach the complete agreement needed if the document is to be adopted as an IDP. They are also aware that any plan will require updating and amendment. If any of the twelve municipalities refuses to amend it in future, the plan could become outdated and irrelevant. For these reasons, the committee recommends that the present document be adopted by the twelve municipalities as an intermunicipal agreement and not as an IDP.

This does not mean that the plan policies cannot be enforced. The policies should be adopted into municipal land use bylaws, and used to guide development agreements. Leduc County and WCPA staff will draft these amendments and bring them to councils for adoption.

Technical Note: comparisons of phosphorus production

1. Cow-calf versus residential

On grey wooded soils, one quarter section of hay plus one quarter section of grazing, totalling 320 acres (130 hectares) will support about 60 cows with calves at foot, assuming a free range, non-intensive grazing scheme. (Source: Lloyd Giebelhaus, Alberta Agriculture, Sangudo, 785-2266.)

Each cow produces about 18 kg/yr of phosphorus, so the total production from the half section is 60 times 18 = 1,080 kg/yr. As this is produced on 130 hectares, the annual production of phosphorus is about 8.3 kg/ha/yr.

How many humans does it take to produce phosphorus at a rate of 8.3 ha/yr?

A typical adult produces 0.9 kg/yr of phosphorus (McComas, 1993, quoted by Lilley and Earle, page 9), so a density of 9 to 10 humans per hectare will produce about the same phosphorus as a cow-calf herd at normal densities. This is about 2.5 households per hectare or about one household per acre.

Because we want to show a reduction in total phosphorus production, the human density should be less than this. If we aim for a 3x reduction in phosphorus, the target human density should be a maximum of one household per three acres where the choice is between cow-calf operations and human settlement.

2. Grain crops versus forest

Crop land produces phosphorus runoff at a rate of about 50 kg/km²/year, or 0.5 kg/ha/yr. Natural forest produces 80% less per unit area, about 10 kg/km²/yr or 0.1 kg/ha/yr (Hardy, 1983).

Converting one hectare of forest into crop land will therefore increase phosphorus runoff by about 0.5 kg per year. This is about half the mass produced by one adult, so the additional phosphorus produced by a family of three can be offset by converting 3 ha of crop land back to forest.

References

Pigeon Lake Water Quality Study: Hardy Associates, Edmonton, Alberta, 1983

Pigeon Lake Water Quality Study: Lilley Environmental Consulting, Sherwood Park, Alberta, and Dr Chris Earle, Concordia University College, Edmonton, Alberta, 1998

The History of the Pigeon Lake Fishery, 1918 to Present: Vance Buchwald, Fish & Wildlife Services, Alberta Environmental Protection, Edmonton, Alberta, 1994

A Proposed Regulatory Framework for Livestock Feeding Operations in Alberta: Alberta Agriculture, Edmonton, Alberta, 1999, published on the Department's website at www.agric.gov.ab.ca/economic/policy/ilo/main

Copies of these publications can be obtained from West Central Planning Agency at:

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