## APPENDIX E

# How development of land increases storm water runoff and impacts lake water quality: An example from the Long Lake watershed in Washburn County

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### *Introduction*

Development in rural areas can create threats to Washburn County's natural environments. These include habitat fragmentation, introduction of exotic species, and growing traffic volumes on rural roads. One of the more visible effects can be seen in the declining water quality of inland lakes. The relationship between development and water quality is the subject of a great amount of research and analysis.

For many years it was thought that the increase in septic systems and modification of shorelines associated with lakeside development were the primary culprits of lake degradation. These changes do have negative consequences for lakes, but depending on the watershed they can be overshadowed by changes in the landscape that increase the volume and velocity of storm water runoff.

This report summarizes the effects of development away from the lake on runoff and lake water quality, compares runoff to other threats facing lakes, and presents different options for mitigating or preventing the impacts of runoff. The Long Lake watershed in the southeast corner of Washburn County is used to illustrate the impacts and provide concrete suggestions for policy improvement.

### *The basics of lake water quality*

Lakes are complex natural features and are tied to their surrounding landscape through the passage of water. Lakes in Washburn County are continually being replenished with water that falls as precipitation. Most of the water that replenishes the area's lakes falls on land and then flows to the lakes. Streams are an obvious example, but the majority of lake recharging water moves invisibly as groundwater. In Long Lake, for example, about half the water entering the lake comes from groundwater flowing through subsurface springs. One-quarter of the water comes from overland runoff into the lake or its tributaries (including Slim Lake and Flowage and Big and Little Devils Lakes) and the remaining quarter comes from direct rain and snow falling on the lake itself.

Water entering Long Lake brings with it a number of important chemicals that affect the ecology of the lake. These include nutrients that sustain algae, plants, and phytoplankton- the foundation of a lake's food chain. Unfortunately, too many nutrients can lead to excessive increases in plant and algae growth. Phosphorus is an example. Relatively little phosphorous is needed to stimulate plant productivity- one pound of phosphorous yields about 500 pounds of plant growth. A small change in phosphorus can lead to large changes in algae and plant growth. If unchecked, these can lead to reductions in water clarity and lower oxygen levels deeper in the lake. This increased productivity can make the lake less appealing for swimming and fishing.

***Runoff and phosphorous***

Groundwater and precipitation usually contain relatively low levels of phosphorous. Phosphorous is a rather “sticky” chemical- it binds to soil and other particles. After precipitation hits the ground it begins to run downhill. Along the way, it picks up organic matter and soil, increasing its phosphorous content. As runoff settles in ponds and puddles, it moves down through the soil to replenish groundwater. the “sticky” phosphorous in the water becomes bound to soil particles and taken up by terrestrial plants (grasses, forbs, trees and shrubs). The result is groundwater that is relatively low in phosphorous, even though the puddles and ponds that replenish the groundwater may be high in phosphorous. In this way, soil and roots work as phosphorus filters.

Not all storm water and snowmelt runoff ends up in small ponds and puddles. When the water is transported directly to lakes, surface runoff is not filtered by the ground or plants and can directly deliver high concentrations of phosphorous to lakes. Urban and agricultural areas can lead to increased surface runoff and subsequently deliver more phosphorus to lakes- the runoff itself is considered a pollutant, hence the term “non-point pollution”.

To reduce runoff entering our lakes, we can reduce the volume of runoff created and slow down the runoff that does form. Natural conditions in Washburn County’s glaciated landscape did a very good job of this: vegetation and permeable soils resulted in little runoff and when runoff was created, the surface of the land was very irregular and rough, providing many places for water to pond and infiltrate. These pitted, irregular surfaces can be contrasted to farmland where tillage and drainage have smoothed and straightened water pathways to allow runoff to “shed” more rapidly. These activities “connect” the watershed to the lake in a way that accelerates the movement of nutrients and sediments to the lake.

The agricultural landscape can be further contrasted to more developed areas where roads, driveways and homes are intentionally designed to eliminate infiltration and maximize the speed at which storm water is transported away. These impervious surfaces are surrounded by a heavily modified landscape that is also engineered to move runoff and snow melt away as quickly as possible, lest too much water get into basements or under roads and undermine these structures. Ponds and wet depressions are also eliminated to make yard care easier and reduce mosquito breeding areas. But where does all this water- water that used to infiltrate into the ground- go? Almost always the water is directly channeled to lakes.

The simple elimination of the filtering process of infiltration ensures that storm water and snowmelt will be higher in phosphorous than it would have been had it settled into the groundwater table. There is another factor, however, that makes development and agricultural runoff into lakes even more potent. As the velocity of water increases, so does its ability to carry solid and dissolved matter. When areas are developed and drained, the storm water is forced to move faster and faster to its new resting spot- the lake. As it speeds up, it carries with it more sediment and organic matter that bring their own phosphorous loads. These are deposited into the lake where the phosphorous becomes “unbound” and feeds algae and lake plant growth.

In summary, the re-shaping of the land from agriculture and development reduces the portion of rain and snow can infiltrate into the ground. This increases the volume of nutrient rich surface runoff. The increased amount of runoff is also directed to the lake faster, carrying with it more and more phosphorous. How does this increase in phosphorous loading compare to other water threats such as septic systems or other nutrient sources?

***Runoff compared to other nutrient sources***

Though septic systems are not designed to filter nutrients (they are meant to eliminate bacteria) they can do a good job of reducing phosphorous when compared to direct discharges into lakes. This is due to phosphorous' ability to bind to solid matter. As liquid waste passes through drain fields, the phosphorous can attach to soil and can be taken up by plants. There is a possibility that soil will become saturated with phosphorous- this is particularly likely in sandy soils that are difficult for chemicals to bind to. Systems can also be damaged or poorly maintained and as a result, they can "fail" to filter discharge and the related phosphorous can end up in the lake.

The amount of water associated with septic system outputs pales in comparison to the volume associated with surface runoff. Recall that surface runoff yields one quarter of Long Lake's total water input- this is over 3 billion gallons a year. Average household water use is about 125,000 gallons annually. A large portion of this is for plant and yard care, and this average represents year-round residences. In Long Lake, each household may transfer about 50,000 gallons annually to a septic system. There are approximately 750 systems on the lake and its upstream tributaries, yielding about 37.5 million gallons of effluent, or 1% of the amount of water coming from surface runoff.

The 1994 lake study reinforces the minor component of septic systems for Long Lake, estimating that they contribute between .3 to 8.8 percent of the total phosphorous entering the lake. Surface runoff, by comparison, yields about half the total current phosphorous found in the lake. Even if all the septic systems were to fail, their contribution of phosphorous would be relatively minor. It is estimated that one person per year generates one pound in phosphorous waste; assuming 1,000 year-round residents on a lake like Long Lake, complete system failure would yield 1,000 pounds of phosphorous, less than half the amount currently contributed by surface runoff.

The same lake study points out that increased surface runoff from development and the phosphorous it would bring to the lake is the most pressing issue, concluding that "*the long-term preservation of current water quality of Long Lake appears feasible. The key to preservation is the control of development throughout the lake's watershed.*"

Two complimentary strategies can be readily employed to bring about such watershed management. The first and somewhat simpler step is to require that new development be done on very large lot sizes, thus minimizing the relative amount of impervious surface and developed landscape accompanying new construction. This can be accomplished through town or county level planning and land use regulations.

The second step is to require that more dense developments, when allowed, be accompanied with a suite of best management practices (BMPs) to minimize the amount of runoff created and increase on-site infiltration. Such BMPs include steps in development design such as minimizing the footprint of buildings and construction envelopes to protect natural plants and soils, maintaining short driveways, and clustering buildings to eliminate the need for new roads. Structural BMPs include creating storm water infiltration basins, rain gardens, and rain barrels.

Unlike lot sizes, which can be easily determined before development begins, BMPs require detailed pre-construction designs as well as on-site inspections both at the time of construction and into perpetuity. For this reason, lot size requirements are seen as the more feasible approach for immediately limiting the impact of development on runoff and water quality in rural areas such as Long Lake. As local capacity develops, BMPs may become a more attractive option and could be employed more frequently, though such development would still need to conform to the community's goals and objectives expressed in their comprehensive plans.

The following section describes how lot sizes and BMP requirements might be tailored to meet water quality goals.

***Lot sizes, surface runoff and phosphorous transport***

The attached diagrams show how runoff characteristics change as a lot becomes divided into smaller and smaller parcels. Going from natural conditions (40 acre lot) to intense development (1 acre lots) increases phosphorous loading *ten times*, from .8 pounds to 8 pounds. This is just from precipitation and does not include phosphorous loading from erosion and sediments. And while a net gain of 7 pounds of phosphorous may not sound like much, remember that a single pound of phosphorous produces 500 pounds of algae. So, in the case above, the development of one 40 acre lot into 40 one-acre residential lots yields on average 3,500 *new* pounds of algae each and every year after it is constructed. Because the lake cannot assimilate all this new growth, the amount of algae in the lake will accumulate over time. Future development in the watershed will almost certainly have a negative impact on lake water quality.

***Enacting BMP and lot size requirements for protecting surface water quality***

As discussed above, best management practices (BMPs) are a suite of methods for reducing storm water runoff and additional nutrient transport to a lake. These BMPs can mitigate the effects of increased development and impervious surface, but two actions may be necessary to make them effective. First, when new projects are being proposed, BMPs should be mandatory whenever the project is likely to yield additional runoff to a surface water body. Secondly, a long-term monitoring and upkeep agreement is needed to ensure that they are maintained indefinitely.

The comprehensive planning underway in Washburn County at the county and town levels provides a sound basis for developing land division ordinances that effectively manage the impacts of subdivision, development, and impervious surface.

The first step is to establish the level of development that can take place without diminishing the resources and failing to meet water quality goals. As this paper has discussed, large lots may be necessary to accomplish this. Large lots will help ensure that a greater portion of a rural watershed remains in its natural, undeveloped condition. Zoning and subdivision ordinances are two tools that can be used at both the county and town to better control the creation of new small lots and require BMPs as part of the development process. If the county and towns feel that small lots are consistent with their community's overall goals, then requiring stormwater management and infiltration BMPs will still be necessary to minimize runoff effects on lakes, streams and wetlands.

***Conclusions***
It will be no accident if 100 years from now Long Lake and other lakes in Washburn County are still the valuable and unique resources that they are today. To make that future a reality, proactive decisions that protect the landscape- especially its most sensitive components- are needed. Natural drainage pathways will need to be restored. The public, lawmakers, and government staff will need to understand the long-term, cumulative impact of hundreds of seemingly small changes. Consistent and regular monitoring is needed to ensure that lake and watershed health are maintained. Most importantly, concerned people will need to stand up and speak on behalf of the lake and its watershed, advocating that the best choices are made whenever a threat is posed to water quality or ecology.

| Basin | Goal | 1994 Summer Average | 1998-2001 Summer Average | 2002-2003 Summer Average |
|---|---|---|---|---|
| A | 16 ug/L | 16 ug/L | 22 ug/L | 21.5 ug/L |
| B | 17 ug/L | 17 ug/L | 20 ug/L | NA |
| C | 19 ug/L | 19 ug/L | 19 ug/L | NA |
| D | 18 ug/L | 18 ug/L | 20 ug/L | NA |
| E | 17 ug/L | 17 ug/L | 19 ug/L | NA |
| F (between A and B | NA | NA | 20 ug/L | 25 ug/L |

Summer total phosphorous goals from Lake Management Plan and actual averages for sampling stations in Long Lake (measured in micrograms per liter; >20 generally indicates eutrophic conditions)

| Lot Size | Runoff Volume | P loan (pounds) | Effect on Total Annual P Load |
|---|---|---|---|
| 1 | 1.6 billion | +5,250 | +93% |
| 2 | 1.0 billion | +3,500 | +62% |
| 5 | 524 million | +1,750 | +31% |
| 10 | 314 million | +1,000 | +18% |
| 40 | 135 million | +500 | +9% |

Watershed scall effects of residential development (25,000 acres, baseline P load is 5,674 pounds per year, assumes 5% slope and A soils)