Re: Technical Request for Information on Shoreline Erosion, Lake Winnipeg

The watershed planner from Manitoba Water Stewardship's Watershed Planning and Programs Section has requested technical information on shoreline erosion on the southwest side of Lake Winnipeg. This information was requested because shoreline erosion is a concern to the residents of the Netley Creek Watershed. This technical information will be used to help develop the Grassmere/Netley Creek Watershed Integrated Watershed Management Plan (IWMP).

Lake Winnipeg

Geology

The geology of the Netley Creek Watershed varies depending on location. The banks on the west side of Lake Winnipeg are typically composed of lacustrine clay overlying clay till. The lacustrine clay in general is stone free and highly erodible. The underlying till unit contains coarser grained particles such as sand, gravel and cobbles. The percentage of coarse grained material that remains once the fine grained matrix (silt and clay) is eroded ranges between 15% and 20%. Other areas on the west shore of Lake Winnipeg consist of low lying sand and mixed sand and gravel beaches.

Erosion of fine grained material such as clay and silt can easily occur when exposed to water. The amount of erosion and downcutting that occurs depends on water depth. More erosion and downcutting of exposed soil occurs in the shallow water closer to the shoreline than the deeper offshore water. As erosion of a bank progresses, the toe of the bank is undercut and portions of the bank are removed by wave action. If a cohesive material has a sufficient content of boulders and cobbles, after the fine grained material is eroded or washed away, a "lag deposit" of cobbles and boulders is left on the beach. This lag deposit slows the erosion process and reduces the retrogression rate along the shoreline. Removing the "lag deposits" to construct groins or create a sandy beach will result in increased erosion of the shoreline.

The south shore of Lake Winnipeg consists of barrier islands. The general stratigraphy in this area is comprised of sand and gravel deposited by wave action overlying organic clay and peat layers. Lacustrine clay is typically found below the organic layer. The backshore area is marshy and typically floods, especially during large north wind events. The barrier islands are transgressing southward due to isostatic rebound and possibly climate change. It is estimated that the south shore has transgressed southward between 60 metres and 100 metres since 1650 AD. Airphoto analysis has demonstrated that the mouth of the Brokenhead River has retreated inland 200 metres to 300 metres between 1946 and 1987.

Barrier islands are a dynamic beach shoreline. A dynamic beach shoreline consists of enough sand and gravel that the underlying substrate is not exposed to erosion. Dynamic beach shorelines continually recede and accrete due to changes in water levels and wave action. Dynamic beach shorelines are different than eroding shorelines. Eroding shorelines result in a net deficit of material because the volume of material removed from an area by longshore drift is greater than the volume of beach sediment being supplied.

Water Levels

The wind eliminated water level of Lake Winnipeg will change depending on the season and will also change from year to year. The change in Lake Winnipeg water levels is affected by precipitation amounts, evaporation and inflow and outflow to the lake.

In the long term, differential isostatic rebound is also contributing to higher water levels in the south basin. The northern outlet of Lake Winnipeg is rising in elevation faster than the southern end of the lake. This has resulted in Lake Winnipeg water levels rising in the south basin and water transgressing southward across the land. It is estimated that isostatic rebound has resulted in the water level in the south basin rising approximately 20 cm/century over the last three hundred years.

Wind set-up also contributes to fluctuations in water levels in the south basin of Lake Winnipeg. Wind set-up is caused by strong winds, typically in the fall, blowing in one direction over the lake for many hours. Strong winds for a long duration results in increased water levels in the downwind direction and decreased water levels in the upwind direction. The decreased water levels are called wind set-down.

Wave Generation

Waves generated by wind on Lake Winnipeg have caused severe erosion from time to time. The height of a wave is a function of wind speed, wind direction, wind duration and fetch. Wave run-up is a significant concern when large wind events occur for a long duration on Lake Winnipeg. The magnitude of wave run-up is a function of wave height and bank slope. Therefore, a shallower bank slope will experience less wave run-up than a steep bank slope.

Wave overtopping occurs when the height of the land is less than the limit of wave run-up. Wave overtopping can result in backshore flooding and may affect the integrity of erosion protection works or the bank. Typically trash lines found after a storm event indicate the elevation of the wave run-up during that particular storm event.

Natural and Man-Made Erosion Factors

Factors such as bank height, bank slope, geology, groundwater, surface water, loading the top of the bank and vegetation also affect erosion rates. Each of the factors are briefly described below.

Bank height and bank slope affect erosion rates. Typically, steeper banks will experience increased erosion as wave run-up is greater on a steeper slope than on a shallow slope.

Higher banks also typically experience greater landward recession than lower banks due to a decrease in overall bank stability.

Geology is an important parameter that affects erosion rates. The banks on the west side of Lake Winnipeg are typically comprised of 80 % to 85 % silt and clay. Erosion of fine grained material, such as clay and silt, can easily occur when exposed to water. As erosion of a bank progresses, the toe of the bank is undercut and portions of the bank are removed by wave action. The southern portion of Lake Winnipeg consists of barrier islands. These barrier islands are composed of enough sand and gravel that the underlying substrate is not eroded.

The ability of groundwater to move vertically through a bank is controlled by bank geology. Groundwater is typically able to flow vertically through sand but is not able to flow vertically through clay quickly. Groundwater flow that is impeded by a clay layer will typically discharge through a more permeable layer (i.e., thin sand seam) on the bank face. This discharge will cause increased erosion on a bank face. Erosion of a bank face will eventually result in the recession of the shoreline as the undercut portions of the bank are transported into the lake by wave action. A bluff that contains large quantities of groundwater also has reduced ability to resist further bank collapse or bank movement. Therefore, bank movement or bank collapse is more likely to occur when a bank is saturated.

Groundwater table elevations are affected by precipitation (rain and snow), snowmelt and human activities. Drainage issues such as septic fields and perforated holding tanks and leaking swimming pools are also significant as they allow water and waste to drain into the lake potentially contributing to bank erosion and bank stability issues. Lot drainage is also highly influential on shoreline stability, as water percolating into the ground in the vicinity of a steep slope tends to make bank erosion and slope movement more likely. Therefore, directing water from eaves troughs away from the lake or avoiding watering the grass will reduce the potential of bank erosion and bank instability occurring. Additional measures such as interceptor drains, French Drains and tile drains can be installed to collect and remove groundwater as it flows through an impermeable layer. These measures are typically constructed across a slope so that gravity will transport the groundwater flow away from the top of the bank to an appropriate discharge area (for example at the base of the bank along the shoreline). These methods typically utilize a trench covered with gravel and geotextile and possibly a PVC or HDPE perforated pipe. Interceptor drains, French Drains and tile drains are examples of measures that can help transport groundwater in a controlled manner, increase bank stability and reduce bank erosion.

Surface water that flows down the face of a bank also contributes to bank erosion. Uncontrolled drainage of surface water, such as improperly draining field tiles and drainage ditches, can also lead to further bank erosion and bank collapse. Redirecting the surface water away from the top of the slope or providing an erosion resistant drainage channel which transports the water down the bank face in a controlled environment will help minimize surface erosion.

Natural trees, shrubs, willows and grasses with deep roots provide a stabilizing influence and protection from surface erosion. Vegetation has the ability to: reinforce the soil with a root system, remove water from the soil through evapotranspiration, reduce runoff velocity, reduce frost penetration and provide a buttress for large tree roots. Planting native vegetation with deep root systems, especially at the top of the bank, will help protect against surface erosion and provide a stabilizing influence.

Loading the top of a bank with a heavy structure or placing fill on or over the top of the bank has a negative influence on bank stability because the driving force of the bank is increased. This negative influence on bank stability increases the probability that landward recession of the shoreline will occur. Consequently, large structures such as houses and cottages should be offset an appropriate distance from the top of the bank. The advantages of locating a structure a significant distance from the top of a bank include: reduced maintenance and replacement costs, minimal negative impacts on the environment and natural aesthetics and the amenities of the beach may be preserved. A qualified geotechnical engineer should be consulted when determining an appropriate set-back distance.

Shoreline Erosion Protection

Structural and non-structural options can be used on Lake Winnipeg to provide shoreline protection measures. However, the decision to use structural or non-structural options is site dependent and requires a site specific review. A geotechnical engineer should be consulted to determine if a structural or non-structural method of shoreline protection is the best approach.

Two levels of structural shoreline protection are typically used on Lake Winnipeg: heavy protection and light protection. Examples of heavy protection include boulder revetments and seawalls. Examples of light protection include light revetments and bulkheads (timber cribs, gabion bulkheads etc.). Heavy protection is designed to protect the shoreline from erosion during large storm events while light protection provides less resistance to erosion. Light protection is less expensive and may leave more of the beach for enjoyment than heavy protection, but in general the design life is less and maintenance is required more often for light erosion protection. Regardless of the type of shoreline protection constructed, maintenance work will be required. It is recommended that a property owner retain the services of a qualified geotechnical engineer prior to constructing shoreline protection to ensure that the final design plan is properly engineered.

Examples of non-structural shoreline protection options include: re-grading the bank slope, planting vegetation on the bank and controlling the drainage of surface water and groundwater. These options do not address the erosion of the shoreline due to wave action and may only be viable alternatives in very low energy wave environments that do not experience significant erosion.

As noted earlier, vegetation with a deep root system helps bind the soil particles and reduces the surface run off velocity. The vegetation may also provide wildlife or fish habitat. Controlling the drainage of surface water or groundwater with French Drains, tile drains or interceptor drains has a positive influence on bank stability by directing water away from the top of the slope and minimizes bank erosion. Re-grading the bank slope to a shallow slope angle may improve the stability of an over steepened bank that is subjected to significant erosion. Re-grading may also be accompanied by drainage improvements and revegetation.

Red River

Geology

The geology of the Netley Creek Watershed varies depending on location. The stratigraphy and geomorphology of the Red River is different than the stratigraphy and geomorphology of Lake Winnipeg. Stratigraphy is the layering of soil while geomorphology is the study of processes that shape landforms. A typical stratigraphic section along the Red River consists of silty clay and silt interbedded with alluvial (deposited by flowing water) silt and sand overlying lacustrine (ancient lake bed deposits) silty clay. Underlying the lacustrine silty clay is till. Post-glacial flooding, deposition, erosion, vegetation growth and human activity have resulted in the modification of the near surface landscape.

Red River

The Red River is shallow, up to 15 metres deep and 2500 metres wide. The riverbed depth is generally controlled by the underlying dense till or resistive bedrock. The Red River has an average valley gradient of 0.0001. The suspended sediment load in the Red River is 90% silt and clay.

Extremely slow to very slow rotational to translational sliding is common along the Red River. Earth sliding is especially common along the outside bends of the river where the river is immediately adjacent to lacustrine material. However, riverbank failures are not limited to outside bends, and can occur on inside, straight and transition sections of the Red River. Since the residual strength of the soils encountered along the Red River is low, deep seated movements are very easily reactivated by erosion or anthropogenic influences.

Riverbank Characterization

The Red River can be classified according to riverbank geometry. Inside bends typically consist of alluvial sediment while outside bends are comprised of lacustrine material. Transition sections contain alluvial deposits overlying lacustrine material. Floodplain banks are formed by alluvial deposits.

The failure surface for an outside bend of the river is located in cohesive, low strength lacustrine material. The failures are deep seated and typically continue to fail until a slope of 9H: 1V is reached. The greatest amount of slope movement on an outside bend typically occurs in the fall and early spring before the freshet. Outside bends are generally considered stable at a slope of 9H: 1V. At this slope angle, it is believed that quasi equilibrium is reached. History has shown that the potential for slope movement decreases when the slope angle of an outside bend is 9H:1V. Slope movement may extend as far as 80 metres back from the river's edge.

Slope movement along an inside bend of the Red River is typically shallow. History has shown that slope movement along an inside bend typically occurs after high water levels have receded, especially after the spring freshet or high summer water levels. Inside bends are formed by accreting alluvial sediments, primarily silt and sand. Alluvial sediments have a higher strength than lacustrine material; therefore, the banks are stable at a steeper slope angle than outside bends. Slope angles for inside bends typically range from 1H: 1V to 3H: 1V, but a stable slope angle is considered 3H: 1V.

Transition banks are found upstream or downstream of inside or outside bends and include straight sections of the Red River. These banks are typically composed of alluvial sediments overlying lacustrine material. Transition banks may experience deep seated or shallow slope movement, depending on the relative depths of these two soil units. A stable slope angle for a transition bank is considered 6H: 1V.

Floodplain banks are located downstream of an inside bend's apex. These banks are primarily composed of sand and silt and are deposited on the inner bends of the Red River as floodplain deposits. The banks are typically less than 6 metres in height. Floodplain banks typically do not experience significant slope movement.

Natural and Man-Made Erosion Factors

In addition to riverbank characteristics, other factors such as bank height, bank slope, geology, groundwater, surface water, river ice, loading at the top of the slope and vegetation also affect slope movements and erosion rates on riverbanks. Each of these factors is briefly described below.

Bank height and bank slope affect erosion rates. Higher and steeper banks typically experience greater landward recession than lower and shallower banks due to a decrease in overall bank stability.

The ability of groundwater to move vertically through a bank is controlled by bank geology. Groundwater is typically able to flow vertically through sand but is not able to flow vertically through clay easily. Groundwater flow that is impeded by a clay layer will typically discharge through a more permeable layer (i.e., thin sand seam) on the bank face. Groundwater flow that is impeded will typically cause increased erosion on a riverbank face. Erosion of a bank face will result in the landward recession of the riverbank as the undercut portions of the bank are transported down slope and eventually downstream by the river. A riverbank that has an elevated groundwater table also has a reduced ability to resist further bank collapse or bank movement. Therefore, bank movement or bank collapse is more likely to occur when a bank is saturated.

Groundwater table elevations are affected by precipitation (rain and snow), snowmelt and human activities. Drainage issues such as septic fields and perforated holding tanks and leaking swimming pools are also significant as they allow water and waste to drain into the river potentially contributing to bank erosion and bank stability issues. Lot drainage is also highly influential on riverbank stability, as water percolating into the ground in the vicinity of a steep slope tends to make bank erosion and slope movement more likely. Therefore, directing water from eaves troughs away from the Red River or avoiding watering the grass will reduce the potential of bank erosion and bank instability occurring. Additional measures such as interceptor drains, French Drains and tile drains can be installed to collect and remove groundwater in a controlled manner as it flows through an impermeable layer. These measures are typically constructed across a slope so that gravity will transport the groundwater flow away from the top of the bank to an appropriate discharge area (for example at the base of the riverbank). These methods typically utilize a trench covered with gravel and geotextile and possibly a PVC or HDPE perforated pipe. Interceptor drains, French Drains and tile drains are examples of measures that can help transport groundwater in a controlled manner, increase bank stability and reduce bank erosion.

Surface water that flows down the face of a bank also contributes to bank erosion. The drainage of surface water in an uncontrolled or inappropriate manner, such as improperly designed municipal infrastructure and drainage ditches, can also lead to further riverbank erosion and bank movement. Redirecting surface water away from the top of the slope or providing an erosion resistant drainage channel which transports the water down the riverbank face in a controlled environment will help minimize surface erosion.

Natural trees, shrubs, willows and grasses with deep roots provide a stabilizing influence and protection from surface erosion. Vegetation has the ability to: reinforce the soil with a root system, remove water from the soil through evapotranspiration, reduce runoff velocity, reduce frost penetration and provide a buttress for large tree roots. Planting native vegetation with deep root systems, especially at the top of the bank, will help protect against surface erosion and provide a stabilizing influence.

Rising river levels in the spring lift river ice. In some reaches of the Red River, frozen riverbed material and riverbank material is attached to the bottom of the river ice. After the ice breaks into sheets and starts moving downstream, it forms packs. As the ice moves further downstream, it gouges the riverbed and lower banks. As the river levels continue to rise, additional erosion of the riverbed and riverbank occurs.

Loading the top of a bank with a heavy structure or placing fill on or over the top of a riverbank has a negative influence on bank stability. Loading the top of the slope, either from deposition of overbank deposits during flood periods or anthropogenic actions, such as illegal dumping, construction, operation of high speed boats in the summer months or lawn watering are significant contributors to riverbank stability problems. Human activities that have a negative influence on riverbank stability should be minimized. An appropriate setback distance (from the top of the bank) for large structures should be determined by a qualified geotechnical engineer.

Shoreline Erosion Protection

Structural and non-structural options can be used on the Red River to provide riverbank protection measures. However, the decision to use structural or non-structural options is site dependent and requires a site specific review. A geotechnical engineer should be consulted to determine if a structural or non-structural method of riverbank protection is the best approach.

Various riverbank stabilization measures exist for inside and outside bends of the Red River. For the outside bend of the Red River, typically the soft clay is removed and replaced with higher strength rock fill. The rock fill provides a buttressing effect and supports the toe of the bank with material that has a greater unit weight. There a number of methods that utilizes this method of stabilization. Examples of this include shear keys, granular ribs and rock fill columns.

A shear key consists of the excavation of the clay material along a continuous trench at the base of the riverbank. The trench is backfilled with rock fill. The shear key is typically dug into the till unit. Granular ribs are similar to a shear key. A series of trenches are excavated perpendicular to the riverbank. These trenches are backfilled with rock fill at designated offsets along the riverbank. Rock fill columns are utilized where the depth to the till unit exceeds the digging capacity of the machinery (usually 6 to 7 metres). Typically, 2.1 metre diameter boreholes are drilled through the clay material into the hard till layer. The boreholes are backfilled with rock.

For an inside bend of the river, erosion protection can be provided for the entire bank face or only on the lower portion of the slope. The riverbank face is protected with rock (rip rap blanket). A small shear key may also be constructed if necessary.

All of the structural riverbank stabilization measures identified above can be incorporated with additional work such as: slope re-grading, drainage improvements and re-vegetation. Regardless of the type of riverbank stabilization constructed, maintenance work will be required. It is recommended that a property owner retain the services of a qualified geotechnical engineer prior to constructing riverbank stabilization measures to ensure that the final design plan is properly engineered.

Examples of non-structural shoreline protection options include: re-grading the bank slope, planting vegetation on the bank and controlling the drainage of surface water and groundwater. As noted earlier, vegetation with a deep root system helps bind the soil particles and reduces the surface run off velocity. The vegetation may also provide wildlife or fish habitat. Controlling the drainage of surface water or groundwater with French Drains, tile drains or interceptor drains has a positive influence on bank stability by directing water away from the top of the slope and minimizes bank erosion. Re-grading the bank slope to a shallow slope angle may improve the stability of an over steepened bank that is subjected to significant erosion. Re-grading may also be accompanied by drainage improvements and revegetation.

Shoreline Management Approach

A shoreline management approach considers various options for dealing with shoreline and riverbank erosion hazards. It is possible to ignore the hazard and live with the consequences, control building within the hazardous area, move away from the hazardous area, construct shoreline protection/riverbank stabilization measures or take measures to reduce damage when it occurs.

Prior to selecting the shoreline management approach that is most suitable for a site, it is important to consider the following items: long term average erosion rates, prevention and relocation versus structural options, effects of the structure on the beach, total cost of the project, impacts to terrestrial and aquatic environment and coordinated effort with the neighbours.

A property owner needs to consider the total amount of erosion that may occur over a 20 to 50 year period to determine an appropriate setback distance of a structure from the hazard land area. The rate of erosion may vary greatly from year to year so calculating the long term average of shoreline erosion is the best approach.

A property owner may also consider prevention and relocation versus structural options in a shoreline management plan. It is preferable if a structure is located a sufficient distance from the shoreline or riverbank so that it will not be impacted by flooding or erosion hazards. However, if the structure is not appropriately located, relocation is an option. The advantages of prevention and relocation over structural options include: reduced construction, maintenance and replacement costs, minimal negative impact to the environment or down shore shorelines, the natural aesthetics of the beach remain and there is no need for approvals.

When a property owner is considering constructing a shoreline erosion protection or riverbank stabilization measures in front of their property, they will need to recognize that a portion of the beach will be lost when the structure is built. Property owners will need to consider the cost of maintaining, repairing and replacing the structure for the life of the development. Adding the construction costs of the shoreline protection or riverbank stabilization works and the maintenance costs associated with the structure, the owner will need to decide if the project makes economic sense.

Structural shoreline or riverbank protection works may affect the terrestrial and aquatic environment. Therefore, it is important that a proper environmental evaluation be completed to determine if the shoreline protection works will negatively affect the surrounding environment. A shoreline owner who installs shoreline or riverbank protection works that result in a negative impact to other properties may be liable.

It should be recognized that individual assessments are required on a reach by reach basis when structural options are being considered for shoreline or riverbank protection. Shoreline processes can not differentiate between neighboring properties and therefore protection works should be coordinated with adjacent properties. The level or type of protection at adjacent properties needs to be considered at adjacent properties. A coordinated effort can result in reduced overhead costs, material prices and construction costs.

The Lake Winnipeg Shoreline Management Handbook is an excellent resource for private landowners who reside on Lake Winnipeg. The handbook provides a brief synopsis on the basic shoreline erosion processes, information on selecting a shoreline management approach and an overview of various shoreline protection measures.

Approvals, Permits and Licenses

A property owner must determine ownership of the land on which shoreline protection works or riverbank stabilization measures will be built so the appropriate approvals, permits and licenses are obtained prior to construction. This can be accomplished by reviewing the Certificate of Title and establishing the limits of property in the field with a legal land survey. A property owner must obtain approval from the appropriate authorities before constructing a structure on land that is not owned by the builder.

In some cases, a Public Reserve or Crown Reservation may lie between the waterside boundary of a lot and the shoreline. The Reserve may belong to the Province, Rural Municipality, Local Government District or Town, which may have by-laws pertaining to the use of the Reserve. A property owner would need to obtain permission from the appropriate authority that has jurisdiction over the Reserve prior to constructing shoreline protection works or riverbank stabilization measures on the Reserve.

The property owner will need to contact their local Planning District to determine if a building permit is required when constructing shoreline protection works or riverbank stabilization measures. The Province of Manitoba does not have the legislated authority to issue permits for shoreline protection works. The Department of Fisheries and Oceans Canada (DFO) need to review all shoreline or riverbank protection works that will be constructed on Lake Winnipeg or any water body that supports fish or fish habitat. Further information on the approval process is given below. Under the Fisheries Act, no one may carry out work that will cause harmful, alteration, disruption or destruction (HADD) of fish habitat unless it is authorized by DFO. A property owner will also need to contact the Canadian Coast Guard if the proposed shoreline protection works or riverbank stabilization measures extend into the water or where it may interfere with the navigation under the *Navigable Waters Act*.

Shoreline Erosion Technical Committee (SETC)

The Shoreline Erosion Technical Committee (SETC) is a multi-disciplinary Committee composed of representatives from local, provincial and federal governments that provide technical advice on shoreline erosion issues free of charge. The SETC provides suggestions towards the design and construction of shoreline protection works and riverbank stabilization measures when an application for shoreline protection works is forwarded to the Committee from the local Planning District or development permitting authority. Representatives from the various levels of government will provide comments on the site specific review through the SETC's response.

DFO partners with the SETC during the site specific review of the proposed shoreline protection works and riverbank stabilization measures. Fisheries and Oceans will provide comments on site specific review through the SETC's response to the application. This coordinated application process eliminates the need for an individual to submit a separate application to DFO. If an individual does not submit an application through this process for a coordinated review by the SETC, obtaining site specific review and approval from DFO for shoreline works will be the responsibility of the parties conducting the work.