APPENDIX

RLRC BROCHURES
GIS THEMATIC MAPS
LAND TRANSFORMATION MODELING
BIBLIOGRAPHY
A set of seven brochures provide information and promote the Red Lake River Corridor; this includes a corridor brochure and a brochure for each of the six segments. A river map, a description of the river segment, points of interest, emergency information, and safety information are in each brochure. The brochures are on the following pages.
SAFETY FIRST

Start your trip with the proper safety equipment. Coast Guard approved personal flotation devices are required by law and should be worn at all times. Paddles often break; carry a spare. Don’t overload a canoe, never carry more than three people.

Consider river levels when planning a trip. Both high and low water levels may mean dragging your canoe more than paddling it. Shrubbery streams overhanging branches are often tricky to negotiate. Underwater branches can easily trip a canoe. Watch for branches and rocks in the water. Always be aware of dams along the river. Portages may be necessary.

Trip Planning - Travel with a companion or group. Plan your trip with a map and advise someone of your departure and arrival times. Most people paddle two to three river miles per hour. On windy days it may be difficult to paddle even downstream along portions of the Red Lake River.

Bring a first aid kit that includes waterproof matches, Leave only footprints, take only photographs (a few fish perhaps too). You must pack out all trash. If you see trash, pack out what you can to help keep the river clean.

Rest Areas and Camping Sites - Public rest areas are available along the route to rest, picnic, and explore. Camp only in designated areas. Be sanitary. Use designated toilet facilities, or bury human waste away from the river. Bring drinking water. It is only available at a limited number of rest areas. Drinking river water is not recommended; but if you do, it must be treated. Respect private property. Stop only at designated sites, unless you have land owner permission to access the camp their land. Much of the shore is private property.

Hydrologic Information - Always research the water levels of the river prior to your departure. Also look at flood forecasts. River level information is available for Red Lake, High Landing, Thief River Falls, Red Lake Falls, and Crookston online via the National Weather Service Office in Grand Forks (NOAA) at www.nrh.noaa.gov/gfl.php. Current and historic water levels are available for Red Lake, High Landing, Crookston, and Fisher at the USGS Water Resources web site at http://waterdata.usgs.gov/mn/nwz4rl/
**Points of Interest**

**Fish and Wildlife** - The Red Lake River supports several species of game fish, including northern pike, walleye, smallmouth bass, rock bass, and channel catfish. The river is particularly noted for channel catfish angling in its lower reaches. Some of the most popular fishing areas for walleye and smallmouth bass are located in Thief River Falls, Crookston, Red Lake Falls, and near the junctions of the Red Lake River with the Thief, Clearwater, and Black Rivers.

Wildlife along the Red Lake River is varied and abundant. Wooded bottomlands provide excellent habitat for wood duck and dove. Fox, weasel, and raccoon range through the region. Bottomlands and cutover lakes attract mallards, blue-winged teal, great blue heron, shovelbills, grebes, numerous species of sparrows, hawks, and bald eagles. Marshes are inhabited by blackbirds, wigeons, wrens, geese, great blue herons and many other species.

**Cultural Information** - In St. Hilaire there is an impressive moss rock stair, mill pond, and reenactment rock sawmill structure that reenacts the logging operations when St. Hilaire was booming and the Thief River Falls was a sawmill town. Also, just downstream from St. Hilaire is the Old Crossing Treaty Historical Park, where in 1833 the Ojibwe Indians signed a treaty ending 11 million acres of land for white settlement in the Red River Valley. This site is also noteworthy as an important river crossing point of the Red River Ojibwe Trail, the tracks of which are partially visible in some areas of NW Minnesota.

**About This River Section**

**Introduction** - The Red Lake River, with its length, width, water quality, and natural beauty, is one of the finest rivers in Minnesota. The river drains a watershed of nearly 6,000 square miles and is the largest tributary of the Red River of the North in the United States. It accounts for 13% of the land area in the Red River Basin, but contributes 33% of the flow. The watershed is one of the largest sub-basins in the state of Minnesota. The Red Lake River is the only river to flow through all three of Minnesota’s biomes: boreal forest, deciduous forest, and prairie.

The river is of unique interest in the Red River Basin for its water quality, fish and wildlife habitat, biodiversity, and recreational value. Recreational uses include boating, canoeing, kayaking, fishing, hunting, bird watching, tubing, swimming, relaxing, cross-country skiing, snowmobiling, and ice-skating. It is the only river in northwestern Minnesota to be designated by the Department of Natural Resources (DNR) as a Canoe and Small Boat Route.

**Water Characteristics** - The Red Lake River is generally a smooth-flowing river. A series of boulevard-style rapids and pools interrupts the river between St. Hilaire and Crookston, where the river drops 110 feet in 17 miles. Some of these rapids can be Class II during high or low water levels.

**Landscape** - Marshy wilderness, flat farmland, towering eroded cliffs, and steep, wooded banks characterize the Red Lake River at different points. Above the dam at river mile 181, the river flows through marshland in the Red Lake Indian Reservation (travel by permit only). White and yellow water lilies, wild rice, and cattails thrive here. Below the dam the river is flanked by prairie that is at times bright with wildflowers. Trees are sparse and small on the low grassy banks. Near High Landing the trees become larger and the river meanders through farmland. Stands of willow, elm, and cottonwood are interspersed with open fields. Residential development is extensive along the banks at Thief River Falls, where a functioning hydro-electric dam creates a reservoir for about 1.5 miles upstream.

Below St. Hilaire the banks steepen and become heavily wooded. High cliffs are first encountered near Red Lake Falls. Entire hillsides, eroded during spring floods, have spilled into the river here. In its lower reaches the river meanders through farmland and stands of elm, willow, and cottonwood.
SAFETY FIRST

Start your trip with the proper safety equipment. Coast Guard approved personal floatation devices are required by law and should be worn at all times. Paddles often break; carry a spare. Don’t overload a canoe; never carry more than three people.

Consider river levels when planning a trip. Both high and low water levels may mean dragging your canoe more than paddling it. Snag-ridden streams with overhanging branches are often tricky to navigate. Underwater branches can easily tip a canoe. Watch for branches and rocks in the water. Always be aware of dams along the river. Portages may be necessary.

Trip Planning - Travel with a companion or group. Plan your trip with a map and advise someone of your departure and arrival times. Most people paddle two to three river miles per hour. On windy days it may be difficult to paddle even downstream along portions of the Red Lake River.

Bring a first aid kit that includes waterproof matches. Leave only footprints; take only photographs (a few fish perhaps too!). You must pack out all trash! If you see trash, pack out what you can to help keep the river clean.

Rest Areas and Camping Sites - Public rest areas are available along the route to rest, picnic, and explore. Camp only in designated campgrounds. Be sanitary! Use designated toilet facilities, or bury human waste away from the river. Bring drinking water. It is only available at a limited number of rest areas. Drinking river water is not recommended, but if you do, it must be treated. Respect private property. Stop only at designated sites unless you have landowner permission to access/camp their land. Much of the shore is private property.

Hydrologic Information - Always research the water levels of the river prior to your departure. Also look at flood forecasts. River level information is available for Red Lake, High Landing, Thief River Falls, Red Lake Falls, and Crookston online via the National Weather Service Office in Grand Forks (NWS) at www.nws.noaa.gov/oh/fghfphp. Current and historic water level data are available for Red Lake, High Landing, Crookston, and Fisher at the USGS Water Resources web site at http://waterdata.usgs.gov/mn/nwis/wa.
Points Of Interest

A carry-in site at the Neptune Bridge provides the first access downstream of the Red Lake Indian Reservation. River Valley Access is about 3.4 miles downstream of the Red Lake Indian Reservation about 12 miles upstream from High Landing. The access site allows room for parking, but the access itself is sometimes muddy and slippery.

The section of river from Neptune Bridge Access to High Landing traverses primarily agricultural lands. Scenery is open and pastoral. During buggy years, this section of the river might be more enjoyable than others, particularly on a breezy day.

Paddling is well suited for novice canoeists, as river currents are typically slow (except during spring flooding and after heavy rainstorms). Additional carry-in access is located at the River Valley bridge.

The High Landing boat ramp is located 1/2 mile down a gravel road at the Pennington Co. Rd. 24 bridge. The site is an excellent landing for timber harvest on the river from logging times in the early 1800's. River character is still dominated by agricultural lands, but the segment is a transition zone to more wooded riparian areas. Water levels and river current are typically appropriate for novice canoeists.

A carry-in access site is located at Kraska Crossing located at the Pennington Co. Rd. 22 bridge 12.5 miles (20.1 km) downstream from High Landing. Kraska Crossing at low water levels is a bit muddy. Sweeney Bridge provides the next carry-in access site 9.5 mi. (15.3 km) downstream from Kraska Crossing.

There are several boat ramps and carry-in access sites as the river flows through Thief River Falls city limits. Centennial Park has a boat ramp, parking, bathrooms, drinking water, and a shelter. Big Scout Park has a boat ramp and parking. L.B. Hartz Park has a carry-in access, parking, bathrooms, and a campground. Oakland Park has a boat ramp.

Disclaimer: This map is not intended as a sole source of navigational information. The website has done its best to ensure the accuracy of places, names, and prices mentioned, but they cannot be held responsible for any inaccuracies or changes in the data. The map is provided as a guide and should not be relied upon for navigation. This information is not updated, and the use of this map is at your own risk. The map is not intended for navigational use. The map is provided as a guide and should not be relied upon for navigation.
SAFETY FIRST

Start your trip with the proper safety equipment. Coast Guard approved personal flotation devices are required by law and should be worn at all times. Paddles often break; carry a spare. Don’t overload a canoe; never carry more than three people.

Consider river levels when planning a trip. Both high and low water levels may mean dragging your canoe more than paddling it. Snag-ridden streams with overhanging branches are often tricky to navigate. Underwater branches can easily trip a canoe. Watch for branches and rocks in the water. Always be aware of dams along the river. Portages may be necessary.

Trip Planning - Travel with a companion or group. Plan your trip with a map and advise someone of your destination and expected times. Most people paddle two to three river miles per hour. On windy days it may be difficult to paddle even downstream along portions of the Red Lake River.

Bring a first aid kit that includes waterproof matches. Leave only footprints; take only photographs (a few fish perhaps too). You must pack out all trash. If you see trash, pack out what you can to help keep the river clean.

Rest Areas and Camping Sites - Public rest areas are available along the route to rest, picnic, and explore. Camp only in designated campsites. Be sanitary! Use designated toilet facilities or bury human waste away from the river. Bring drinking water. It is only available at a limited number of rest areas. Drinking river water is not recommended, but if you do, it must be treated. Treat private property. Stop only at designated sites unless you have land owner permission to access/camp their land. Much of the shore is private property.

Hydrologic Information - Always research the water levels of the river prior to your departure. Also look at flood forecasts. River level information is available for Red Lake, High Landing, Thief River Falls, Red Lake Falls, and Crookston online via the National Weather Service Office in Grand Forks (NSA) at www.crh.noaa.gov/gfelfp. Current and historical water level data are available for Red Lake, High Landing, Crookston, and Fisher at the USGS Water Resources web site at http://waterdata.usgs.gov/mt/nwrf/sf.

EMERGENCY INFORMATION

911: Identify where you are prior to calling for help!

Police and Sheriff

<table>
<thead>
<tr>
<th>Location</th>
<th>Phone Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crookston Police</td>
<td>218-231-3511</td>
</tr>
<tr>
<td>East Grand Forks Police</td>
<td>218-773-1104</td>
</tr>
<tr>
<td>Pembina County Police</td>
<td>218-625-6611</td>
</tr>
<tr>
<td>Polk County Sheriff</td>
<td>218-251-0431</td>
</tr>
<tr>
<td>Red Lake County Sheriff</td>
<td>218-354-2929</td>
</tr>
<tr>
<td>Red Lake Falls Police</td>
<td>218-253-2966</td>
</tr>
<tr>
<td>Thief River Falls Police</td>
<td>218-626-6161</td>
</tr>
</tbody>
</table>

Hospitals

<table>
<thead>
<tr>
<th>Location</th>
<th>Phone Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>River Valley Healthcare, Crookston</td>
<td>218-231-8200</td>
</tr>
<tr>
<td>929 2nd Avenue, E.</td>
<td></td>
</tr>
<tr>
<td>Thief River Falls, MN 56701</td>
<td>218-681-1600</td>
</tr>
</tbody>
</table>

MeritCare, East Grand Forks 621 Dakota Avenue East Grand Forks, MN 56721 218-773-5500

Weather Information Crookston Airport (automated) 218-251-3180

Chamber of Commerce Crookston 118 Main Street W. Crookston, MN 56716 218-251-4320

Thief River Falls 2717 Hwy 59 S.E. Thief River Falls, MN 56701 www.ci.thief-river-falls.mn.us

Greater Grand Forks Visitors Bureau 4201 Gateway Drive Grand Forks, ND 58201 800-896-4566 www.visithlemanbks.com

Red Lake Falls City Office 103 2nd Street South St. Paul, MN 55155-4640 651-638-9564

To view or download the DNR map of the Red Lake River, visit our website at www.dnrstate.mn.gov or contact the DNR at DNR Information Center PO Box 123, St. Paul, MN 55164-0123 651-296-6000

Section – 2 of 6 Red Lake River Canoe & Small Boat Brochure

Thief River Falls to Red Lake Falls

Distance: 36 miles (57 km)

Map 2 of 7
Points of Interest

There are several boat ramps and carry-in access sites as the river flows through Thief River Falls’ city limits. Centennial Park has a boat ramp, parking, bathrooms, drinking water, and a shelter. Boy Scout park has a boat ramp and parking. L.B. Hart Park has a carry-in access, parking, bathrooms, and a campground. Oakland Park has a carry-in access, parking, bathrooms, and drinking water, and a shelter. The next access is at Island Park in St. Hilaire about 10 miles (16km) downstream from Thief River Falls. Island Park has carry-in access, parking, bathrooms, a campground, and a picnic area. There is no river access for the next 22 miles until Red Lake Falls. Sportman’s Park has a boat ramp, parking, bathrooms, drinking water, a campground, and a picnic area. Riverside Park has a distant carry-in access, parking, bathrooms, drinking water, a campground, and a picnic area.

Disclaimer: This map is not intended as a sole source of navigational information. The authors have made a strong effort to ensure the accuracy of places, names and phone numbers, but they cannot be responsible for changes that may have occurred since the printing of this map. This content is available online at https://www.dnr.legioncreek.org.

About This River Section

Between Thief River Falls and Red Lake Falls the river flows through primarily floodplain forest, but agriculture and rural residential lands also are visible from the river. This section is probably the fastest flowing portion of the Red Lake River. Class II rapids are more common here and boulder riffles make passage at low water difficult (below a stage of about 7.5 ft. at the gauging station in Crookston).

Oakland Park is just downstream from Thief River Falls and is a Pennington County Park.
SAFETY FIRST

Start your trip with the proper safety equipment. Coast Guard approved personal flotation devices are required by law and should be worn at all times. Paddles often break; carry a spare. Don’t overload a canoe; never carry more than three people.

Consider river levels when planning a trip. Both high and low water levels may mean dragging your canoe more than paddling it. Snag-ridden streams with overhanging branches are often tricky to negotiate. Underwater branches can easily tip a canoe. Watch for branches and rocks in the water. Always be aware of dams along the river. Portages may be necessary.

Trip Planning - Travel with a companion or group. Plan your trip with a map and advise someone of your departure and arrival times. Most people paddle two to three river miles per hour. On windy days it may be difficult to paddle even downstream along portions of the Red Lake River.

Bring a first aid kit that includes waterproof matches. Leave only footprints, take only photographs (a few fish perhaps too!). You must park out all trash. If you see trash, pick it up. If you can help keep the river clean.

Rest Areas and Camping Sites - Public rest areas are available along the route to rest, picnic, and explore. Camp only in designated campsites. Be sanitary! Use designated toilet facilities, or bury human waste away from the river. Bring drinking water. It is only available at a limited number of rest areas. Drinking river water is not recommended; if you do, it must be treated. Respect private property. Stop only at designated sites unless you have land owner permission to access/camp there land. Much of the shore is private property.

Hydrologic Information - Always research the water levels of the river prior to your departure. Also look at flood forecasts. River level information is available for Red Lake, High Landing, and Thief River Falls. Red Lake Falls and Crookston online via the National Weather Service Office in Grand Forks (NOAA) at www.weather.gov/gdf/operations. Current and historic water level data are available for Red Lake, High Landing, Crookston, and Fisher at the USGS Water Resources web site at http://waterdata.usgs.gov/mn/nwis/rt.

EMERGENCY INFORMATION

911: Identify where you are prior to calling for help!

<table>
<thead>
<tr>
<th>Police and Sheriff</th>
<th>218-281-3111</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crookston Police</td>
<td>218-772-1550</td>
</tr>
<tr>
<td>Pine River Police</td>
<td>218-681-6000</td>
</tr>
<tr>
<td>Polk County Sheriff</td>
<td>218-281-9300</td>
</tr>
<tr>
<td>Red Lake County Sheriff</td>
<td>218-281-2360</td>
</tr>
<tr>
<td>Thief River Falls Police</td>
<td>218-681-6000</td>
</tr>
</tbody>
</table>

Hospitals

| Boundary Healthcare, Crookston | 218-281-9300 |
| Alton Northwest Clinic, Thief River Falls | 218-681-6000 |

Local Mosquito Information

| Northwest Clinic, Thief River Falls | 218-281-3180 |
| Chamber of Commerce, Crookston | 218-281-4000 |
| Thief River Falls | 218-681-3720 |
| Greater Grand Forks Visitors Bureau | 218-681-3900 |
| Red Lake Falls City Office | 218-281-2843 |

Red Lake River Canoe & Small Boat Brochure

Section – 3 of 6

Red Lake Falls to Huot

Distance: 13.5 miles (22 km)

Map 3 of 7
POINTS OF INTEREST

Paddling from Sportsman’s Park in Red Lake Falls to Old Crossing Treaty Park near Hull takes about 4.5 hours. The river meanders 13.5 miles (21.8 km) through floodplain forest and impressive eroding clay banks. The current is more rapid in this stretch than along most of the river (except from St. Hilaire to Red Lake Falls) and could be tricky at low flow. The river bottom is composed of sandy-clay in black water areas and gravel, cobbles and some boulders in faster riffles (Class II rapids). Beginners will be challenged and more advanced canoeists will enjoy the rapid yet relaxing ride.

ABOUT THIS RIVER SECTION

Sportsman’s Park, in the city of Red Lake Falls, lies at the confluence of the Red Lake River and the Clearwater River, the historic site of sturgeon spawning runs as well as the original Red Lake Falls Sawmill. There are several amenities in the park including a boat ramp access. The park is near the Rails-to-Trails walkway for easy connection to town. Camping is permitted (check for fees). From the park it is about 13.5 river miles (21.8 km) to the next access at Old Crossing Treaty Historic Park in Hull. At average water levels, the journey takes about 4.5 hours. The current can be swift and flows through several class II rapids. Canoeing at low water levels can be difficult. The trip from Red Lake Falls to Hull offers spectacular views of eroding clay banks. There is also supposed to be excellent beeh fishing nearby. Old Crossing Treaty Park lies near the confluence of the Red Lake River and the Black River. There are several amenities in the park including boat ramp access. There are two units to the park, one just north of the boat ramp along the west side of the Black River and one at the boat ramp. Adjacent to the park is a DNR Wildlife Management Area where hiking and wildlife viewing opportunities exist. Across the river is land owned by the University of Minnesota, managed by the Crookston Campus.

Old Crossing Treaty Park was the site of an 1863 treaty in which the Ojibwe ceded about 11 million acres of the Red River Valley (an area approximately 180 miles long and 127 miles wide) to the United States government for $515,000 and various goods, provisions, and presents. In 1933 the site was commemorated with a lifesized bronze statue of an Ojibwe man holding a peace pipe. The same site was well-known even before the treaty. For about 30 years in the mid-1800’s, it was the location chosen by oxcart drivers, freight goods on the Pembina Trail between St. Paul and Winnipeg, to cross the Red Lake River.

Backwards—This map is not depicted as a sole source of navigational information. The authors have made a strong effort to ensure the accuracy of places, names and phone numbers, but they cannot be responsible for changes that may have occurred since the printing of this map. This map is not eligible for sale to the public. Further information is available online at www.dnr.state.mn.us/parks/asi/redlake falls.html (The Ojibwe Nation of Red Lake Falls), www.parks.state.mn.us/asi/redlakefalls.html (The Minnesota Department of Natural Resources), wwwanimations.com (the future Midwest Project). This brochure contains excerpts from the Midwest Project. Financial support was provided by the Heritage Foundation, Inc., and the Minnesota Historical Society. Permission is granted to reproduce this brochure, in part or in whole, with the understanding that no additional fee shall be charged for such reproduction. The University of Minnesota is an equal opportunity employer. Contents were not been reviewed by the University of Minnesota.
SAFETY FIRST

Start your trip with the proper safety equipment. Coast Guard approved personal flotation devices are required by law and should be worn at all times. Paddles often break, carry a spare. Don’t overload a canoe, never carry more than three people.

Consider river levels when planning a trip. Both high and low water levels may mean dragging your canoe more than padding it. Snag-ridden streams and overhanging branches are often tricky to negotiate. Underwater branches can easily tip a canoe. Watch for branches and rocks in the water. Always be aware of dams along the river. Portages may be necessary.

Trip Planning - Travel with a companion or group. Plan your trip with a map and advise someone of your departure and arrival times. Most people paddle two to three river miles per hour. On windy days it may be difficult to paddle even downstream along portions of the Red Lake River.

Bring a first aid kit that includes waterproof matches. Leave only footprints, take only photographs (a few fish perhaps too). You must pack out all trash. If you see trash, pack out what you can to help keep the river clean.

Red Areas and Camping Sites - Public red areas are available along the route to rest, picnic, and explore. Camp only in designated campgrounds. Be sanitary! Use designated toilet facilities, or bury human waste away from the river. Bring drinking water. It is only available at a limited number of red areas. Drinking river water is not recommended, but if you do, it must be treated. Respect private property. Stop only at designated sites unless you have land owner permission to access/camp their land. Much of the shore is private property.

Hydrologic Information - Always research the water levels of the river prior to your departure. Also look at flood forecasts. River level information is available for Red Lake, High Landing, Thief River Falls, Red Lake Falls, and Crookston online via the National Weather Service Office in Grand Forks (NOAA) at www.chr.nws.noaa.gov/wfo/gfz.php. Current and historic water level data are available for Red Lake, High Landing, Crookston, and Fisher at the USGS Water Resources web site at http://waterdata.usgs.gov/mn/nwis/wrl.

EMERGENCY INFORMATION

911: Identify where you are prior to calling for help!

Police and Sheriff

Crookston Police
218-281-3111

East Grand Forks Police
218-773-1104

Wrenshall Police
218-691-8161

Pikeland County Sheriff
218-329-5031

Red Lake County Sheriff
218-735-2900

Red Lake Falls Police
218-641-2155

Thief River Falls Police
218-621-5181

Hospitals

Morning Star Health Care, Crookston
203 S. Minnesota St.
Crookston, MN 56716

Alto NorthEast Clinic, Thief River Falls
120 Lafayette Ave. B.
Thief River Falls, MN 56701

HerkCra, East Grand Forks
231 Charles Avenue
East Grand Forks, MN 56721

Weather Information

Crocation Airport (estimated)
218-281-3018

Chamber of Commerce

Crookston 115 Fletcher Street
Crookston, MN 56716

www.visitcrookston.com

Thief River Falls
2017 Hwy SS S.E.
Thief River Falls, MN 56701
www.thiefriverfalls.mn.us

Greater Grand Forks Visitors Bureau
426 Gateway Drive
Grand Forks, ND 58203
www.visitgrandforks.com

Red Lake Falls City Office
260 2nd Street Southwest P.O. Box 37
Red Lake Falls, MN 56750
www.redlakefalls.com

RED LAKE RIVER CANOE & SMALL BOAT BROCHURE

Section 4 of 6

Hut to Crookston

Distance: 23 miles (36 km)

Map 4 of 7
POINTS OF INTEREST

The section from Old Crossing Treaty Park to Crookston is beautifully forested with some agricultural lands and residential areas approaching Crookston. The river slows dramatically as it moves from the Lake Agassiz Beach Ridge formations into the flat and wide Red River Valley. This section of the river is still floodable even at very low river stages near 48, at the gauging station in Crookston and is a popular fishing hole.

Scale note - This map is not intended as a sole source of navigational information. The authors have made a strong effort to ensure the accuracy of streets, names and phone numbers, but they cannot be held liable for errors. This information was produced by M. Knepper, L. Leppig, and L. Loging at the University of Minnesota, Crookston. D. Pennerman and D. Votava were at the Center for Scientific and Cultural Affairs of the University of Minnesota, Morris. A portion of this model was adapted from a recreation site map created by the Red River Valley Regional Economic Development Partnership with the Nature Northwest Project. This brochure integrates excerpts from DNR publications. Financial support was provided by the Northwest Regional Sustainable Development Partnership and the National REAP (Resource and Energy Assurance Project). The University of Minnesota is an equal opportunity educator and employer. This brochure was printed on recycled paper with soy ink and has been reviewed by the University of Minnesota.

ABOUT THIS RIVER SECTION

Old Crossing Treaty Park lies near the confluence of the Red Lake River and the Black River. There are several amenities in the park including boat ramp access. There are two units to the park, one just north of the boat ramp along the west side of the Black River and one at the boat ramp. Adjacent to the park is a DNR Wildlife Management Area where hiking and wildlife watching opportunities exist. Across the river is land owned by the University of Minnesota, managed by the Crookston Campus. Old Crossing Treaty Park was the site of an 1885 treaty in which the Ojibwa ceded about 11 million acres of the Red River Valley (an area approximately 180 miles long and 177 miles wide) to the United States government for $110,000 and various goods, provisions, and presents. In 1933 the site was commemo-rated with a life-sized bronze statue of an Ojibwa man holding a peace pipe. This same site was well-known even before the treaty. For about 30 years in the mid-1900s it was the location chosen by scott drivers, freighting goods on the Pembina Trail between St. Paul and Winnipeg, to cross the Red Lake River. For the last 20 years, Old Crossing Treaty Park has been used by L'Association des Français du Nord (The Association of the French of the North) to host a multi-cultural Chouteauque French Festival in late August. The festival involves the Ojibwa, Metis, Red River Valley residents of French-Canadian descent, and people of other ethnic heritage.

There is no river access for the next 25 miles between Hust and Crookston. The Polk Co. Rd. 21 bridge 5.5 miles east of Crookston has no official access point, but it is often possible to access the river through the tall grasses. Between the bridge and Crookston's Central Park, there is one low-head dam that you will need to portage. Stay close to the north bank (right bank) as you approach the dam for an easy portage. The Central Park boat launch is the most convenient exit in Crookston. Downstream from Central Park, a dangerous dam was converted to a rock riffle early in 2006. It can be safely portaged along the right (east) bank. Central Park is host to several summer events including OxCart Days. Restrooms and drinking water are available. There is a movie theater, library, and general stores within walking distance. This access point is upstream of the converted rock riffle in Crookston, so it is disadvantageous to exit the river here. The access at the park is good and minimizes the mud factor. Polk County Highway 705 Boat Access provides additional access in Crookston.
SAFETY FIRST

Start your trip with the proper safety equipment. Coast Guard approved personal flotation devices are required by law and should be worn at all times. Paddles often break; carry a spare. Don’t overload a canoe; never carry more than three people.

Consider river levels when planning a trip. Both high and low water levels may mean dragging your canoe more than paddling it. Snag-ridden streams with overhanging branches are often tricky to navigate. Underwater branches can easily tip a canoe. Watch for branches and rocks in the water. Always be aware of dams along the river. Portages may be necessary.

Trip Planning - Travel with a companion or group. Plan your trip with a map and advise someone of your departure and arrival times. Most people paddle two to three river miles per hour. On windy days it may be difficult to paddle even downstream along portions of the Red Lake River.

Bring a first aid kit that includes waterproof matches. Leave only footprints, take only photographs (a few fish, perhaps too). You must pack out all trash! If you see trash, pick it up. What you can to help keep the river clean.

Reef Areas and Camping Sites - Public reef areas are available along the route to rest, picnic, and explore. Camp only in designated campsites. Be sanitary! Use designated toilet facilities, or bury human waste away from the river. Bring drinking water. It is only available at a limited number of reef areas. Drinking river water is not recommended, but if you do, it must be treated. Respect private property. Stop only at designated sites unless you have land owner permission to access/camp their land. Many of the shore is private property.

Hydrologic Information - Always research the water levels of the river prior to your departure. Also look at flood forecasts. River level information is available for Red Lake, High Landing, Thief River Falls, Red Lake Falls, and Crookston online via the National Weather Service Office in Grand Forks (NOAA) at www.nws.noaa.gov/gfk/graip. Current and historic water level data are available for Red Lake, High Landing, Crookston, and Fisher at the USGS Water Resources web site at http://waterdata.usgs.gov/mn/nwis/rt.

EMERGENCY INFORMATION

<table>
<thead>
<tr>
<th>Police and Sheriff</th>
<th>Phone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crookston Police</td>
<td>218-281-3111</td>
</tr>
<tr>
<td>East Grand Forks Police</td>
<td>218-773-1104</td>
</tr>
<tr>
<td>Pembina County Sheriff</td>
<td>218-681-8181</td>
</tr>
<tr>
<td>Pembina County Sheriff</td>
<td>218-281-0431</td>
</tr>
<tr>
<td>Red Lake County Sheriff</td>
<td>218-255-5066</td>
</tr>
<tr>
<td>Red Lake Falls Police</td>
<td>218-255-2566</td>
</tr>
<tr>
<td>Thief River Falls Police</td>
<td>218-881-6161</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hospitals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Riverview Healthcare, Crookston 305 B. Minnesota St. Crookston, MN 56720</td>
</tr>
<tr>
<td>218-281-8200</td>
</tr>
<tr>
<td>Altrock Northeast Clinic, Thief River Falls 120 Ulline Ave. S. Thief River Falls, MN 57701</td>
</tr>
<tr>
<td>218-881-0600</td>
</tr>
<tr>
<td>MedCare, East Grand Forks 621 Colville Avenue East Grand Forks, MN 56721</td>
</tr>
<tr>
<td>218-773-5800</td>
</tr>
<tr>
<td>Weather Information</td>
</tr>
<tr>
<td>Crookston Airport (automated)</td>
</tr>
<tr>
<td>218-281-3018</td>
</tr>
<tr>
<td>Chambers of Commerce</td>
</tr>
<tr>
<td>Crookston 116 Fisher Street Crookston, MN 56715</td>
</tr>
<tr>
<td><a href="http://www.crookstownchamber.com">www.crookstownchamber.com</a></td>
</tr>
<tr>
<td>Thief River Falls 2017 Hwy. 59 S.E. Thief River Falls, MN 57701 <a href="http://www.cs">www.cs</a> thiefriver falls mn.gov</td>
</tr>
<tr>
<td>218-881-3700</td>
</tr>
<tr>
<td>Greater Grand Forks Visitors Bureau 4251 Gateway Drive Grand Forks, ND 58203 <a href="http://www.grandforks.com">www.grandforks.com</a></td>
</tr>
<tr>
<td>507-885-4565</td>
</tr>
<tr>
<td>Red Lake Falls City Office 100 2nd Street Southwest P.O. Box 37 Red Lake Falls, MN 56750 <a href="http://www.redlakefalls.com">www.redlakefalls.com</a></td>
</tr>
<tr>
<td>218-255-2664</td>
</tr>
<tr>
<td>Fisher City Office 513 Park Avenue P.O. Box 158 Fisher, MN 56723</td>
</tr>
<tr>
<td>218-591-2207</td>
</tr>
</tbody>
</table>

To view or download the DNR map of the Red Lake River, High Landing, and Fisher, visit the DNR website at www.dnr.state.mn.us or contact the DNR at: DNR Information Center 500 Lafayette Road St. Paul, MN 55155-4040 651-296-6777 888-MINN DNR (646-3677)

Section – 5 of 6

Red Lake River Canoe & Small Boat Brochure

Crookston to Fisher

Distance: 27 miles (43km)

Map 5 of 7
POINTS OF INTEREST

The Polk County Highway 75 Boat Access Ramp is a basic site providing river access only. The concrete boat ramp is located on the Polk County Highway 75 bypass around Crookston. This stretch of the river is a popular fishing destination. The recommended method of travel to Fisher (no boat landing) and East Grand Forks (next boat ramp) is by motor boat. Canoeing this stretch is possible, but there is currently no public camping until East Grand Forks. The distances are long (2-3 miles to Fisher) and the river is very sluggish; however, fishing is fun, especially for catfish.

Disclaimer – This map is not intended as a sole source of navigational information. The authors have made a strong effort to ensure the accuracy of points, but previous changes that may have occurred since the printing of this map are not included or accounted for. The publication was produced by D. Knowlton, J. Langlie, and L. Langlie at the University of Minnesota, Crookston. C. Fernandez and D. Verfaillie at the Center for Changing Landscapes, University of Minnesota, Duluth, and in cooperation with the Minnesota Department of Natural Resources. Financial support was provided by the Northwest Minnesota Sustainable Development Partnership and the Northeast Minnesota Foundation. The University of Minnesota is an equal opportunity educator. Contents have not been reviewed by the University of Minnesota.

ABOUT THIS RIVER SECTION

Central Park is host to several summer events including Ol' Cani Days. Restrooms and drinking water are available and there is a movie theater, library, and general stores within walking distance. This access point is upstream of the converted rock riffle dam in Crookston, so it is convenient to exit the river here. The access at the park is good and minimizes the need for portaging. Polk County Highway 75 Boat Access provides additional access in Crookston.

The Crookston to Fisher segment is a long haul of 22.3 miles with no access sites in between. Paddling from the Highway 75 Boat Access to Fisher’s Landing will probably be a long 10-hour day of continuous paddling. The river is slow and meanders in almost complete circles. If you’re apprehensive about such a long trip, a small skiff with a motor might be the most enjoyable mode of transport through this section. Perhaps future improvements to the trail will provide a few more access points and possibly some areas to camp for the night.

There are no dams between these points and the river is almost always navigable, even during low flows. Fishing is good, as catfish become more abundant and the presence of pike, walleye, smallmouth, drum, and goldeye provide a diverse catch.
SAFETY FIRST

Start your trip with the proper safety equipment. Coast Guard approved personal flotation devices are required by law and should be worn at all times. Paddles often break; carry a spare. Don’t overload a canoe; never carry more than three people.

Consider river levels when planning a trip. Both high and low water levels may mean dragging your canoe more than paddling it. Snag ridden streams with overhanging branches are often tricky to negotiate. Underwater branches can easily tip a canoe. Watch for branches and rocks in the water. Always be aware of dams along the river. Portages may be necessary.

Trip Planning - Travel with a companion or group. Plan your trip with a map and advise someone of your departure and arrival times. Most people paddle two to three river miles per hour. On windy days it may be difficult to paddle even downstream along portions of the Red Lake River.

Bring a first aid kit that includes waterproof matches. Leave only footprints; take only photographs (a few fish perhaps too). You must pack out all trash! If you see trash, pack out what you can to help keep the river clean.

Rest Areas and Camping Sites - Public rest areas are available along the route to rest, picnic, and explore. Camp only in designated campsites. Be sanitary! Use designated toilet facilities, or bury human waste away from the river. Bring drinking water. It is only available at a limited number of rest areas. Drinking river water is not recommended; but if you do, it must be treated. Respect private property. Stop only at designated sites unless you have land owner permission to access/camp their land. Much of the shore is private property.

Hydrologic Information - Always research the water levels of the river prior to your departure. Also look at flood forecasts. River level information is available for Red Lake, High Landing, Thief River Falls, Red Lake Falls, and Crookston online via the National Weather Service Office in Grand Forks (NOAA) at www.nwsc.noaa.gov/gflightga. Current and historic water level data are available for Red Lake, High Landing, Crookston, and Fisher at the USGS Water Resources web site at http://waterdata.usgs.gov/mnwri/satl.

EMERGENCY INFORMATION

911: Identify where you are prior to calling for help!

Police and Sheriff

Crookston Police
218-281-3111

East Grand Forks Police
218-775-1104

Pennington County Police
218-681-8161

Red Lake County Sheriff
218-281-2431

Red Lake Falls Police
218-281-2356

Thief River Falls Police
218-681-6161

Hospitals

Riverview, Crookston
218-281-2020

Altra Southwest Clinic, Thief River Falls
1201 Liberty Ave, S
Thief River Falls, MN 56701

MCI, East Grand Forks
621 3rd Avenue
East Grand Forks, MN 56721

Weather Information

Crookston Airport (automated)
218-281-2618

Chambers of Commerce

Crookston
115 Fisher Street
Crookston, MN 56716
www.visitcrookston.com

Thief River Falls
207 Hwy 59 S E E
Thief River Falls, MN 56701
www.thiefrivervalley.com

Greater Grand Forks Visitors Bureau
4251 Gateway Drive
Grand Forks, ND 58203
www.grandforksarea.com

Red Lake Falls City Office
350 2nd Street South
Red Lake Falls, MN 56750
www.redlakefalls.info

Fisher City Office
310 Park Avenue P.O. Box 158
Fisher, MN 56723
218-691-2007

To view or download the DNR map of the Red Lake River or more water information, visit the DNR website or call the DNR office. Ask an officer or contact the DNR at 1-651-296-6000,

DNR Information Center
500 Lafayette Road
St. Paul, MN 55155-4040

Section – 6 of 6

Red Lake River
Canoe & Small Boat Brochure

Fisher to East Grand Forks

Distance: 29 miles (46 km)

Map 6 of 7

161
**Points of Interest**

Like the Crookston to Fisher segment, this section of the Red Lake River is a long haul. Paddling from the unofficial carry-in access at Fisher’s Landing to East Grand Forks will probably be a long 11-12 hour day of constant paddling. The river is slow and meanders in almost complete circles. One could cut the trip short by negotiating the gravelly and muddy banks at the Polk County Highway 220 bridge about 5 miles upstream of East Grand Forks. Or one could start a trip here for a short leisurely afternoon float into town. If you’re apprehensive about such a long trek, a small sail with a motor might be the most enjoyable mode of transport through this section. Perhaps future improvements to the trail will provide a few more access points and possibly some areas to camp for the night. There are no dams between these points and the river is almost always navigable, even during low flows. Fishing is good, as catfish become more abundant and the presence of pickerel, walleye, smallmouth, drum, and goldeneye provide a diverse catch.

**About This River Section**

Much is being done in the city of East Grand Forks to change the riverfront after the devastating flood of 1997. A 1,200-acre greenway is being constructed along the floodplains of the Red River and the Red Lake River, where buildings and homes once stood. The Red River State Recreation Area is part of a planned regional greenway which someday may reach from Lake Traverse to Winnipeg.

As part of the state recreation area, a full-service campground will be constructed adjacent to downtown East Grand Forks. In addition, there will be group camping areas, a picnic shelter, an outdoor amphitheater, a new local launching area, parking areas, and restrooms, and lots of open space for community events. There will also be an extensive trail system, including walking trails within the greenway and about 20 miles of bicycle trails along the new and improved levees designed to protect the community from 200-year flood events. Pedestrian bridges will connect to other trails and park areas in Grand Forks, ND and South of the Red Lake River.

The proposed Regional Visitor and Interpretive Center would act as:

- The gateway to the natural resources of the Minnesota and Red River Valley
- The tourist and recreational hub for local, regional and state areas

**Disclaimer** - This map is not intended as a sole source of navigational information. The authors have made a strong effort to ensure the accuracy of places, names and phone numbers, but they cannot be held responsible for changes that may have occurred since printing of the map. This material is available online at [www.redrivertrail.org](http://www.redrivertrail.org).

**Acknowledgments** - We gratefully acknowledge the contributions of G. L. Ledingham, L. Ledingham, and G. L. Ledingham of the University of Minnesota, Conservation C. L. Ledingham and D. C. Ledingham at the Center for Changing Landscapes, University of Minnesota, CAFA, and in cooperation with the Nature Northeast Project. This brochure contains excerpts from CDF publications. Financial support was provided by the Northwest Regional Sustainable Development Partnership and the Northwest Cooperative Fish and Wildlife Research Unit, an opportunity employer. Content has not been reviewed by the University of Minnesota.
The first step in the design process is analyzing the landscape to understand its complex layers of geology, landform, vegetation, history and culture. In order to perform the analysis, GIS data was collected and then processed into different layers according to themes. The themes each become an individual map. Like laying a transparency over another, these thematic maps are layered over each other to reveal relationships within the complexity of the landscape.

Thirteen data layers were chosen to be combined into the thematic maps: bedrock geology, surficial geology, infrastructure, elevation, hydrology, original vegetation, native plant communities, biodiversity sites, national wetlands inventory, land use, land cover, population change, and land ownership. The thematic maps then produced, at the scale of the Red Lake River Watershed, are: Hydrology, Geological Association, Land Use, Infrastructure, Original Vegetation, Topography, and Cultural Resources.

Analyzing the landscape in this layered manner serves as the basis for developing a regional identity through design. Mapping the attributes of a region allows the design to celebrate the uniqueness of the area through use of regional materials, native vegetation and local form vocabulary.
HYDROLOGY
ORIGINAL VEGETATION
TOPOGRAPHY
CULTURAL RESOURCES

Red Lake River Watershed Boundary
- Historic structures
- Public water access
- Canoe trail
- County lines
- Snowmobile trails
- County: forest & parks
- SNA
- Nature Conservancy
- WMA
- NWR
- City parks
- City lines
- Reservation
- Private land
THE LAND TRANSFORMATION MODEL (LTM)

The LTM model is a digital tool developed by Michigan State University to assist planners and resource managers to develop improved decisions that affect the environment and local to regional economies. The LTM uses recent land use change, population growth, transportation, proximity or density of important landscape features such as rivers, lakes, recreational sites, and high-quality vantage points as inputs to model future land use change.

The LTM model employs Artificial Neural Networks, similar to the intricate pathways established in the human brain. The Artificial Neural Net is a process that utilizes a machine learning approach to numerically solve relationships between inputs and outputs (Michigan State University 1996). The LTM relies on Geographic Information Systems (GIS), artificial neural network routines, land use data from at least two dates, and customized geospatial analysis tools. Raw GIS data (e.g., thematic layers) is first acquired, then processed, and converted to an ARC/INFO GRID format with cell sizes of 30m x 30m.

INPUTS TO THE LTM MODELLING PROCESS

LANDSAT THEMATIC MAPPER IMAGES:

LandSat satellites capture moderate resolution images of the earth from space. For this project, analysts classified LandSat TM5 image data from around 1991 and 2000 to generate land cover/land use maps of the study area. Specifically, three Landsat scenes were needed to cover the extent of the Minnesota River Valley; specifically these were path-29 row-29, path-28 row-29, and path-27 row-29. The subsequent land cover classification of the 1991 base layer used one TM image from each scene. The image dates used, in order of path and row given above, were August 19th 1992, August 26th 1991, and September 6th 1992. Images were selected based on their quality (i.e., lack of clouds and haze) and nearness to the base date of 1991. The 2000 land cover classification used images from the ETM+ sensor corresponding to the dates August 4th 2001, July 23rd 1999, and September 18th 1999. Again all images were chosen based on clarity and nearness to the base date 2000. All the images were rectified to the MDOT road layer, with a final rectification error of less than 15 meters.

The ISODATA algorithm was used to classify the images into the following classes: Water and rivers, lowland forest, upland forest, agriculture/grass, urban and lowland non-forest. These classes were established based on the abilities of the sensor, our research requirements, and by referencing Anderson’s Land Use / Land Cover classification system. The resulting classes are described in table 1. Table 1. Description of land cover/land use classes. Land cover/land use class Description Water and Rivers Permanent open water, lakes Lowland forest Lowland forested area. Forest defined as a minimum of 70% canopy closure. It includes coniferous, deciduous, and mixed forest. Upland forest Upland forest area. Forest defined as a minimum of 70% canopy closure. It includes coniferous, deciduous, and mixed forest. Agriculture/grass Includes planted cropland, rangeland, fallow, and natural grassland. Urban Includes commercial, industrial, residential, and transportation. Lowland non-forest Lands that are sometimes covered with water or have waterlogged soils.
GAP ANALYSIS PROGRAM (GAP) VEGETATION MAP:
The Minnesota GAP vegetation map is a detailed, hierarchically organized vegetation cover map produced by computer classification of combined two-season pairs of early 1990s Landsat imagery. The map was developed as part of the Upper Midwest Gap Analysis Program whose goal it is to maintain biodiversity by identifying those species and plant communities that are not adequately represented in existing conservation lands. There are typically 4 levels or classes in Gap Analysis. The GAP vegetation map was used to create a lowland mask to separate lowland forest areas from lowland non-forest areas in the Landsat images noted above. It also served as an aid to the generation of land cover/land use classifications.

U.S. GEOLOGICAL SURVEY (USGS) DIGITAL ELEVATION MODELS (DEM):
The DEMs were standardized to 30-meter grid cells, UTM Zone 15, NAD83, vertical units in feet and were joined into one statewide file. All the DEMs are Level 2 quality. Level 2 DEMs have been processed or smoothed for consistency and edited to remove identifiable systematic errors. A vertical RMSE of one-half of the contour interval, determined by the source map, is the maximum permitted. Systematic errors may not exceed one contour interval specified by the source graphic.

DEPARTMENT OF TRANSPORTATION 2001 ROADS:
This data set contains roadway centerlines for roads found on the USGS 1:24,000 mapping series. Those roadways that are Interstate, Trunk Highway, or CSAH (county state/aid Highway) are current through the 2001 construction season. Other roads, if not updated, are depicted as shown on the published quadrangle.

HYDROLOGICAL LAKE AND WETLAND DATA:
The 1:100,000 scale hydrography data was derived from USGS Digital Line Graphs (DLG)’s of the same scale. This data contains only the polygon portion of the DLG database. Area features are described as lakes, wetlands, inundated areas, tailings ponds, sewage ponds, fish hatcheries, and other minor water body types.

NATIONAL FOREST:
Natforest, which represents national forest boundaries within the state, is a layer of the State of Minnesota BaseMap 2001 which consists of a number of individual data layers or themes digitized from 1:24000 USGS 7.5-minute quadrangles. These data layers fall into the following broad categories: transportation system, civil and political boundaries, and surface water. Natforest originated as a polygon coverage with the U.S. Forest Service. It is available through the Minnesota Department of Transportation.

INDIAN RESERVES:
Reservin, which represents Indian reservation boundaries within the state, is a layer of the State of Minnesota BaseMap 2001, which consists of a number of individual data layers, or themes digitized from 1:24000 USGS 7.5-minute quadrangles. It is available through the Minnesota Department of Transportation.

CENSUS BLOCK
U.S. Census block level data with population information for 1990 and 2000 was obtained from the U.S. Census Bureau.
Final report findings of the Land Transformation Model as produced by the Remote Sensing Lab, College of Natural Resources, University of Minnesota are contained on the following pages.
Red Lake River Corridor Land Use Change Projections – Preliminary Report

by

Christopher Schwalw, Kristin Page, and Alan Ek
Department of Forest Resources
University of Minnesota
St Paul, MN 55108

First Draft: December 10, 2003
Revised: February 2, 2004

Introduction

As part of the Red Lake River Enhancement Project (hereafter RLREP) land use and land use change along the Red Lake River was classified and projected forward, respectively, with the Land Transformation Model (LTM, Pijanowski, 2001). The baseline land use and projections are to be used in conjunction with the development of a master plan for the Red Lake River corridor. Specifically, a comprehensive development plan that details the development of recreational and other resources for the region is the end goal. The land use projections serve as a means to examine urbanization trends along the Red Lake River and gauge the effect of various explanatory variables and the master plan on potential future urbanization.

The study area for the RLREP is a 5 mi corridor centered on the Red Lake River from Red Lake to its confluence with the Red River in East Grand Forks, MN. The corridor is limited to Minnesota only. This area includes Crookston, Thief River Falls, East Grand Forks and part of the Red Lake Reservation.

The objectives of this study are (i) to create a spatially-referenced database that details, among other attributes, vegetation, hydrology, geology, land use, transportation infrastructure, and, ownership for the entire Red Lake River watershed in Minnesota; (ii) to classify land use along the Red Lake River in 1990 and 2000 based on LandSat imagery; (iii) to project change in land use using a 20 and 50 yr time horizon with the LTM; (iv) to analyze LTM outputs to gauge relative importance of various explanatory variables; and (v) to use the completed master plan for the region as a further input in the LTM model and quantify the effect of the master plan on urbanization.

The first objective, i.e., database creation, is complete. In contrast to the other objectives the database is referenced to the entire Red Lake River watershed. This was done to give a larger data context of spatially adjacent areas for the RLREP. The database provides a baseline on the entire watershed for the classification and projection of land use as well as an aid in the construction of the master plan. The database consists of one ArcGIS® map file with ~25 layers and is available at: http://gis.umn.edu/~kpage/redlakeriver/RedLakeRiverWatershed.zip (check project contacts for current location)

The final objective, i.e., scenario development contingent on the master plan, is under development. The master plan is in the final stages of refinement. Once it is complete the LTM model will be used to gauge the effect of the plan on urbanization.

The remaining objectives deal with preprocessing model inputs, model runs, and post-processing of model outputs (i.e., results) for the LTM. The steps involved are detailed in the following sections.
LAND TRANSFORMATION MODEL

Methods - Preprocessing

Land use classification

The LTM requires as inputs land use at the base year (1990) and the final year (2000). As with all LTM inputs, the files must be in an ASCII grid format (see Pijanowski [2001] for a detailed treatment of format requirements for model inputs) and consistent in spatial extent as well as map model (projection: UTM 15N; spheroid: GRS 1980; datum: NAD 83). LandSat images from 1990 and 2000 as archived by the Remote Sensing Department were used to create land use maps for the base and final years respectively. The anniversary dates were matched as closely as possible relative to the LandSat scenes available. The study site required more two scenes in each year (Table 1) which were merged into a mosaic using histogram matching for the overlapping areas. The 5 mi study corridor was then extracted out of the larger image for classification.

Table 1. Characteristics of LandSat images.

<table>
<thead>
<tr>
<th>Year</th>
<th>Sensor</th>
<th>Acquisition date</th>
<th>Path</th>
<th>Row</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>TM</td>
<td>September 9, 1987</td>
<td>30</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>TM</td>
<td>August 30, 1990</td>
<td>29</td>
<td>27</td>
</tr>
<tr>
<td>Final</td>
<td>ETM+</td>
<td>August 24, 2000</td>
<td>30</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>ETM+</td>
<td>August 01, 2001</td>
<td>29</td>
<td>27</td>
</tr>
</tbody>
</table>

After creating the sub-images for the study site both years’ land use was determined using unsupervised classification. The Iterative Self-Organizing Data Analysis Technique (ISODATA) implemented in ERDAS Imagine v.8.6 (Schroeder and Poucesey, 1997) was used to turn the raw data into a thematic map consisting of 5 land use types (Table 2). The ISODATA routine requires 3 user-defined parameters: number of clusters \( n_\text{i} \), maximum number of iterations (Max), and convergence threshold \( \delta \). As processing time was not a constraint, Max was set to 100 and \( \delta \) to 0.99 – both relatively high values indicative of cheap computer time.

During a broad trial and error search for \( n_\text{i} \), i.e., from 20 to 140 with increments of 20, 69 clusters resulted in good separation between the various land use classes and was retained for both the base and final year.

Table 2. Land use classification used for this study.

<table>
<thead>
<tr>
<th>Land use class</th>
<th>Description</th>
<th>Code</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>Planted croplands, rangeland, fallow and natural grassland, open fields</td>
<td>1</td>
<td>Yellow</td>
</tr>
<tr>
<td>Non-forested shrub</td>
<td>Shrub land with less than 70% canopy closure, riparian zone</td>
<td>2</td>
<td>Brown</td>
</tr>
<tr>
<td>Forest</td>
<td>Forested area with a minimum of 70% canopy closure</td>
<td>3</td>
<td>Green</td>
</tr>
<tr>
<td>Water</td>
<td>Permanent open water, lakes, rivers, and wetlands</td>
<td>4</td>
<td>Blue</td>
</tr>
<tr>
<td>Urban</td>
<td>Any developed land included commercial, industrial, residential, and transportation infrastructure</td>
<td>5</td>
<td>Purple</td>
</tr>
</tbody>
</table>

Ancillary data used to truth the resulting land use maps includes the database developed under the first objective, aerial photos of the forested, eastern portion of the study area, and, for 1990 only, the state-wide
four-tiered land use classification map (e.g. UMGAP, http://www.umesc.unr.edu/umgaphome.html) developed by the Minnesota Department of Natural Resources (DNR) in the 1990's. Apart from visual inspection of ancillary data there was no effort to quantify or qualify the uncertainty in the land use maps.

After the land use maps were created a 5x5 majority filter was used to remove anomalous smaller clusters and smooth class boundaries. Finally, highways were then overlaid on the land use maps and classified as urban. This has implications for the explanatory variables as used in the LTM model. The model calculates rough probabilities of transition to urban based on proximity to the transportation infrastructure (and other driving variables—see below) which was, for this study, represented by major roads in non-urban areas (i.e., cells that were part of the main transport network were classified as urban) embedded in the final land use map.

Before using the map in the LTM the amount of new urban cells was determined as this is used a runtime parameter. This value, arrived at by subtracting urban cells in 1990 from urban cells in 2000, was 10166.

Exclusionary area and population change

Apart from the land use data the LTM requires an ASCII grid of the exclusionary layer. The exclusionary layer is a simple registration of LandSat pixels that can not undergo transition. This includes previously urban areas (including the transportation infrastructure), water (see Table 2), and pixels that have certain ownership characteristics. For this study state (e.g., Waterfowl Production Areas) and federal land holdings (e.g., the Red Lake Reservation) were excluded. The spatial extent of this exclusionary zone, as used for all LTM runs and projections, is based on current (i.e., data references the final year) data.

Population change data is not a required input but has been used in other studies involving the LTM. Given that the temporal indexing implemented in the LTM (Pijanowski et al., 2002b) is related to population change this variable can be viewed as highly recommended although its exact format is left to the user’s discretion. For this study absolute population change per county-subdivision census unit based on the 1990 and 2000 US Census (http://www.census.gov), as downscaled to LandSat 30m pixel, was used. The principal advantage is that these census units generally do not change through time and that any changes either incorporate or disaggregate linearly. Smaller census units allow for finer resolution of population change but are confounded by changes in size, location, and, fractional overlap such that a direct comparison through time is difficult.

Explanatory variables

The LTM model is based on an open interface that uses neural networks (Pijanowski et al., 1997, 2001a,b). As such there is no predetermined set of explanatory variables needed as inputs apart from land use data, the exclusionary zone, and population change. Explanatory variables are chosen that have some relationship with urbanization and land use change based on the particular scenario to be simulated. Furthermore, the structure of neural networks is more amenable to smooth functions (Bishop, 1995). Pijanowski and co-workers have used the model in a variety of geographic regions (e.g., Twin Cities, Detroit, Grand Traverse Bay, Kuala Lumpur, Malaysia). This has led to a growing body of knowledge as to what variables are expedient, available, and provide sensible results. These considerations led to the use of ten facultative explanatory variables (Table 3).
Table 3. Characteristics of facultative explanatory variables.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Euclidean distance to nearest urban area</td>
<td>Potential for organic growth around an existing urban center</td>
</tr>
<tr>
<td>Euclidean distance to nearest federal/state highway</td>
<td>Potential accessibility of a given location to new development</td>
</tr>
<tr>
<td>Euclidean distance to nearest township road</td>
<td>Potential accessibility of a given location to new development; augments distance to highways as these are scarce in the study region</td>
</tr>
<tr>
<td>Euclidean distance to nearest county road</td>
<td>Existence of basic urban amenities such as shopping venues; potential accessibility of a given location to new development</td>
</tr>
<tr>
<td>Euclidean distance to nearest city road</td>
<td>Proxy for city services such as sewers, electricity, cable services</td>
</tr>
<tr>
<td>Euclidean distance to nearest railroad</td>
<td>Access to markets and interregional transportation infrastructure; replacement for distance to Interstate highways</td>
</tr>
<tr>
<td>Euclidean distance to Red Lake River floodplain</td>
<td>Proxy for developable land in general as recent flooding events have pushed developed land out of the floodplain; also represents topography by proxy as the Red Lake River watershed is largely flat outside of the immediate flood plain</td>
</tr>
<tr>
<td>Euclidean distance to the Red Lake River</td>
<td>Incorporates the main feature of the RI.REP into LTM projections; proxy for scenic amenities; desirability of pixel for residential use; high demand development locations</td>
</tr>
<tr>
<td>Euclidean distance to nearest open water excluding the Red Lake River</td>
<td>Scenic amenities as well as tourism and recreation potential; desirability of pixel for residential use</td>
</tr>
<tr>
<td>Absolute change in population from 1990 to 2010</td>
<td>Raw population change as diver if urbanization</td>
</tr>
</tbody>
</table>

* All variables discussed in Pijanowski and co-workers (Pijanowski 2001; Pijanowski et al., 2001a,b, 2002a,b) except the Euclidean distances to the nearest township road, railroad, and floodplain, which are from this study.

Methods - Model Runs

Once all 13 inputs (i.e., two land use inputs, exclusionary zone, and the ten facultative inputs) were completely preprocessed, three LTM model runs were made (Table 4). These runs can be divided into two groups: forecast and simulation.

The two simulation runs use the main LTM graphical user interface (GUI) and predict final year land use based on all inputs. In this case the model compares the actual change in urbanization to the predicted change in urbanization. The model quantifies the discrepancy between observed and predicted change via a change metric (PCM: percent correct match; Pijanowski et al., 2001b) which is the amount of cells correctly transitioned by the model divided by the amount of cells that historically changed to urban over the same time period, expressed as a percentage. In addition to calculating the PCM overall the LTM iteratively removes one of the ten facultative inputs, retests the network, and recalculates the PCM. The change in the PCM based on the removal of a particular predictor quantifies the effect of the dropped predictor on model accuracy. Furthermore, the LTM calculates this metric at various scales (i.e., from 1x1 to 101x101 pixels). Here the model creates a window centered on the pixel in question. At each window size the model looks for
a pair of matching mispredictions. Specifically, the model counts pairs of pixels where (i) one pixel changed in the observed but not predicted land use map and (ii) one pixel did not change in the observed but did in the predicted land use map. Once a pair is found the amount of correctly predicted pixels is incremented by one (see Pijanowski [2001] for a detailed discussion). The justification behind such an analysis is that a model using a coarser spatial resolution would have fewer errors of spatial misregistration. This allows the user to gauge the effect of the predictor at different spatial scales despite having data referenced to only one spatial space—the Landsat 30m pixel for this study.

The forecast run uses stand-alone command line executable included in the LTM distribution. Here the model extrapolates the change in urbanization into the future under the assumption that the same amount of cells that transitioned over the 10 year simulation period will also transition every subsequent 10 years. The executables transition by analyzing transitional probabilities. In the simulation run, which must always precede any forecast runs, the model (i.e., the neural network) calculates the probability of transition to urban for every cell not in the exclusionary zone. The simulation runs take those cells with the highest transition probabilities and changes them to urban. The forecast runs continue this by transitioning those cells that have the highest transition probabilities among the remaining non-urban cells. For this study, land use was forecasted in 2020 and 2050. Unlike the simulation runs, no accuracy metrics are calculated. For both the simulation and forecast runs the LTM generates ASCII grids of predicted land use. These grids were subsequently converted to an ERDAS Imagine file for viewing ease.

### Table 4. Characteristics of LTM model runs.

<table>
<thead>
<tr>
<th>Run</th>
<th>Type</th>
<th>Number of cycles</th>
<th>Predictors iteratively dropped</th>
<th>Computer time*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Simulation</td>
<td>1000</td>
<td>Y</td>
<td>108 hr</td>
</tr>
<tr>
<td>2</td>
<td>Simulation</td>
<td>5000</td>
<td>N</td>
<td>48 hr</td>
</tr>
<tr>
<td>3</td>
<td>Forecast</td>
<td>1000</td>
<td>n/a</td>
<td>5 min</td>
</tr>
</tbody>
</table>

* Runs were executed on a Pentium® 4 1.70 GHz computer with 261.424 KB RAM under Microsoft Windows® 2000 SP4.

Model initialization, apart from the preprocessing of inputs, requires a set of five runtime parameters:

- **number of cells to transition**
- **number of cycles**
- **MSE reporting**
- **value to be transitioned and training factor**

Each parameter, apart from MSE reporting, can affect model performance and will be discussed in turn:

1. **Number of cells to be transitioned**: This is the absolute amount of cells that changed from non-urban to urban, excluding the exclusionary zone, between the base and final year. For this study this value is 10166 cells over the ten year period. This number was retained in both simulation runs and the forecast run—this is the only runtime parameter for forecast runs. In other words, the trend in urbanization was linearly extrapolated into the future. While this assumption is problematic it is currently the best approach based on the LTM and this study.

2. **Number of cycles to train**: This is the amount of training cycles or epoch of the underlying neural network. In general, the higher the number the longer (i.e., more computer time) the network will spend in learning the data. There is typical a point of marginal gain or even of performance degradation (see Bishop [1995] for a detailed discussion). Pijanowski and co-workers (cf. Pijanowski, 2001; Pijanowski et al., 2001b, 2002a, b) use from 500 to 5000—with 1000 (S. Pithadia, pers. comm.) being adequate. This study used 5000 without iteratively dropping predictors and 1000 with iteratively dropping predictors (cf. Table 4).

3. **Number of cycles at which the MSE should be displayed**: This controls how often the MSE of the network (i.e., analogous to the MSE in regression) is displayed by the model. As this value is not saved in the current version of the LTM model it is purely cosmetic and has no effect on model performance or computing time. This study used 100 for all runs.
iv. **Value to be transitioned**: This is the numeric value that represents the urban land use type in the ASCII grid land use input files. Urban was coded as “5” in this study (cf. Table 2).

v. **Training factor**: This parameter also relates to the neural network. It is the denominator of the fraction of data used by the network to learn. “2” corresponds to using half of the data to learn and half to validate. “3” corresponds to using only one-third of the data to learn and the reminder to validate the network. For this study we split that data evenly and used the value “2”.

**Results and discussion**

Among other applications of the LTM the RLREP compared favorably with regards to PCM (Table 5). This accuracy was achieved despite using only 1000 train cycles as opposed to 5000 for Kuala Lumpur. Also, the performance was achieved using a Landsat pixel of 30m; a much finer spatial resolution than the 150m cell for Kuala Lumpur. In general, a high PCM makes forecasts based on the LTM more believable.

<table>
<thead>
<tr>
<th>Study area</th>
<th>PCM</th>
<th>Training cycles</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red Lake River Corridor</td>
<td>57%</td>
<td>1000</td>
<td>This study</td>
</tr>
<tr>
<td>Red Lake River Corridor</td>
<td>62%</td>
<td>5000</td>
<td>This study</td>
</tr>
<tr>
<td>Twin Cities 7-county metro, Minnesota</td>
<td>37%</td>
<td>500</td>
<td>Pijanowski et al., 2001b</td>
</tr>
<tr>
<td>Detroit 7-county metro, Michigan</td>
<td>34%</td>
<td>500</td>
<td>Pijanowski et al., 2001b</td>
</tr>
<tr>
<td>Grand Traverse Bay Watershed, Michigan</td>
<td>48%</td>
<td>5000</td>
<td>Pijanowski et al., 2002b</td>
</tr>
<tr>
<td>Kuala Lumpur, Malaysia</td>
<td>73%</td>
<td>5000</td>
<td>Pijanowski, 2001</td>
</tr>
</tbody>
</table>

While increasing the number of training cycles five-fold increased the PCM by 5%, a relative increase of ~10%, computing time factored largely into the decision to retain 1000 cycles for subsequent analysis. This comparison is meant to offer a means to gauge the effect of increased training for this particular dataset.

The relative importance of each explanatory variable shows a gradual change from the most important, Euclidean distance to Red Lake River floodplain, to least important, Euclidean distance to nearest urban area (Table 6). The relative ranking is also largely constant over spatial scale (i.e., the range of windows from 1x1 to 101x101; not shown) except for Euclidean distance to highways and railways which continuously decline as window size decreases. Nonetheless, the overall stability of the rankings is at odds with previous studies with the LTM (cf. Pijanowski, 2001).

In general, the distances to any water feature in the study area was the most important set of predictor variables. However, it is difficult to translate the changes in PCM into an exact quantification of a particular variable’s overall contribution as the PCM metric is not calculated by the neural network per se (see ftp://ftp.sas.com/pub/neural/importance.html for a useful discussion on gauging the contributions of inputs to neural networks). As such, the ranking is instructive as a rough guide only and the change in PCM should not be viewed as an endorsement to exclude or include a particular predictor.
Table 6. Relative importance, in ascending order, of predictors as measured by change in PCM when removed.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Change in PCM (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Euclidean distance to nearest urban area</td>
<td>0.0033</td>
</tr>
<tr>
<td>Euclidean distance to nearest county road</td>
<td>0.0279</td>
</tr>
<tr>
<td>Euclidean distance to nearest township road</td>
<td>0.0356</td>
</tr>
<tr>
<td>Euclidean distance to nearest city road</td>
<td>0.0492</td>
</tr>
<tr>
<td>Euclidean distance to nearest federal/state highway</td>
<td>0.0504</td>
</tr>
<tr>
<td>Absolute change in population from 1990 to 2000</td>
<td>0.0657</td>
</tr>
<tr>
<td>Euclidean distance to nearest railroad</td>
<td>0.0727</td>
</tr>
<tr>
<td>Euclidean distance to nearest open water</td>
<td>0.0811</td>
</tr>
<tr>
<td>excluding the Red Lake River</td>
<td></td>
</tr>
<tr>
<td>Euclidean distance to the Red Lake River</td>
<td>0.1240</td>
</tr>
<tr>
<td>Euclidean distance to Red Lake River</td>
<td>0.1253</td>
</tr>
</tbody>
</table>

The importance of water features (i.e., the three most important variables according to change in PCM; cf. Table 6) is logical as the Red Lake River is the most salient feature in terms of recreation and development in the study area. There are other rivers in the study area (e.g., Red River) which have the same function for smaller regions with the overall study area—as indicated by the ranking of Euclidian distance to nearest open water excluding the Red Lake River. The relative lack of influence on overall accuracy exerted by Euclidian distance to nearest county road and urban areas does not match results for other LTM studies (e.g., Fismanowski et al., 2001a) where these predictors are more important. Also, transportation features figure prominently (i.e., are ranked higher) in other LTM studies. It is suggested here that the relationship between the actual Red Lake River channel, its floodplain, and existing urban cells act as surrogates for transportation features and Euclidian distance to urban areas. In the context of recent flooding events and the developmental pull of the river this seems plausible but is merely speculative at this point.

Using the LTM as a tool to forecast future is arguably the most compelling use of the model. The predominant visual impression of land use in both 2020 and 2050 (Figure 1) is that each subsequent time period creates a set of concentric circles around already existing urban centers. Except for Fisher and Thief River Falls, there are no new urban clusters but merely an organic growth of existing urban areas along the urban – non-urban interface. Between 2000 and 2020 a new urban cluster does form close to Fischer along the Red Lake River and several new clusters form along a rough North-South axis between Thief River Falls and Red Lake Falls. Ultimately, in 2050, Thief River Falls, the urban area with the most vigorous population and urban cell growth in this study, merges with St. Hilaire and some of the new urban clusters (Figure 2).

Assuming the demand for urban land remains constant; the LTM outputs were used to construct population estimates for all urban areas in the study site (Table 7). The demand for urban land was calculated based on the final year and is the ratio of population to number of urban cells by urban cluster. The relative ranking of the population centers, relative to the base year, remains unchanged with Thief River Falls posting the largest population gain. In general, the predicted emergence of new urban cells indicates a sizeable increase in population. This holds for all urban clusters expect of River Lake Falls, which did not grow (i.e., no new
Figure 1. Land use change as predicted by the LTM for the western, urbanized part of the study area.
Figure 2. LTM predicted land use change (2000 to 2050) from Thief River Falls to Red Lake Falls. Note the merging of St. Hilaire with Thief River Falls and the emergence of new urban clusters along the Red Lake River and the main thoroughfare (dashed pink line).

Thief River Falls
Red Lake Falls
Corridor

New urban clusters from 2020 to 2050
New urban clusters from 2000 to 2020
Rte 32
Red Lake River
Red Lake Falls

Land Use
Agriculture
Non-forested shrub
Forest
Water
Urban (2000)
Urban (2020)
Urban (2050)

urban cells) during the entire study timeframe. Thief River Falls, including the new urban clusters and St. Hilaire, and Fisher almost triple from 2000 to 2050 in terms of total number of urban cells. East Grand Forks and Crookston also grow but more modestly (i.e., less than a doubling). From 1990 to 2020, overall population growth for the entire study site was 640 people, with the maximum population growth per county-subdivision of 1140 and a minimum of -1200, but 1315 when referenced only to the 5 urban centers (cf. Table 7). For the forecast time periods (2000-2020 and 2020-2050) this figure was, as a decadal rate, 5389 and 4642 respectively. The variability in population growth from the initial 10 yr period suggests some
LAND TRANSFORMATION MODEL

intra-regional migration at relative constant total population. This attribute of the study site is lost during LTM forecast runs.

Table 7. Population of urban centers (i.e., those centers classified as urban with population > 200) in the study area by year based on US Census data (1990, 2000) and LTM forecasts (2050).

<table>
<thead>
<tr>
<th>City</th>
<th>1990</th>
<th>2000</th>
<th>2020</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crookston</td>
<td>8119</td>
<td>8192</td>
<td>12126</td>
<td>14438</td>
</tr>
<tr>
<td>East Grand Forks</td>
<td>7501</td>
<td>8658</td>
<td>10745</td>
<td>12775</td>
</tr>
<tr>
<td>Fisher</td>
<td>413</td>
<td>435</td>
<td>566</td>
<td>1215</td>
</tr>
<tr>
<td>Red Lake Falls</td>
<td>1481</td>
<td>1540</td>
<td>1540</td>
<td>1540</td>
</tr>
<tr>
<td>Thief River Falls*</td>
<td>8308</td>
<td>8312</td>
<td>12938</td>
<td>21872</td>
</tr>
<tr>
<td>Total*</td>
<td>25822</td>
<td>27137</td>
<td>37915</td>
<td>51840</td>
</tr>
</tbody>
</table>

* Includes and ultimately merges with St. Hilare

Summary and concluding remarks

Based on the classified images corresponding to 1990 and 2000, the LTM showed an overall accuracy of 57%, which compares favorably to other studies using the model. Water features figured prominently in determining the quality of LTM outputs whereas transportation features were relatively less important. Using the LTM to forecast urbanization in the RLEP until 2020 for the 5 mi corridor showed new urban cells occurring in association with pre-existing urban centers except for between Red Lake Falls and Thief River Falls and a small cluster southeast of Fisher. Between 2020 and 2050 Thief River Falls merges with St. Hilare and other new urban clusters. Overall the LTM predicts an increase in the area classified as urban from 2.1% in 2000 to 3.8% in 2050 with a concomitant population increase of 24,703 (191% increase relative to 2000). Further LTM runs for the RLEP will include additional data layers and the master plan itself (currently under development). Subsequent analyses should offer more detailed picture regarding future urbanization trends in the study area.

References


Minnesota Pollution Control Agency. “Glacial Lake Agassiz and the Red River Valley.”


Schwert, Donald P. “Why is the Red River of the North so vulnerable to flooding?” Fargo Geology. North Dakota State University. 2001. 29 September 2005 <www.ndsu.edu/fargo_geology/whyflood.htm>


RED LAKE RIVER CORRIDOR
PROJECT MEDIA COVERAGE

“Project Aims to Enhance Red Lake River, Corridor Enhancement Project supports recreational, economical development on river” Grand Forks Herald, ND. 27 July 2005.


“River Corridor Project meets in TRF” Northern Watch, Thief River Falls, MN. Saturday 28 June 2003.


“Group seeks funds for river corridor” The Thief River Falls Times, MN. Wednesday Sept. 4 2002.


“Ramping up access” Grand Forks Herald, ND. Friday 16 Aug. 2002.


WEBSITES THAT MENTION THE PROJECT ARE:
http://www.nwmf.org/2003-NMF_Annual_Report.pdf on page 9 of the PDF
http://www.ci.east-grand-forks.mn.us/council/2002/081502.htm mentioned in the EGF minutes
http://www.mn.nrcs.usda.gov/partnerships/pembina/projects.htm
http://www.redlakefalls.com/red_river_corridor.htm