LECTURE 17:
JUNE 5, 2014

WATER

HUMAN INTERVENTIONS IN THE HYDROLOGICAL CYCLE &

WATER QUALITY AND WATER AS HAZARD & MAP LITERACY 4 (ML.4)

Text Reference: Dearden and Mitchell (2012), Ch. 11, pp. 374-416

Geography/Environmental Studies 1120
T. Randall, Lakehead University, SA 2014

Outline

- Upcoming:
  - **June 11 (Wed, Map Quiz)**
  - **June 12 (Thurs, Presentations)**
  - **June 12 (Papers Due – change!)**
  - **June 13 (Fri, Last Class)**
  - **June 16 (Mon, Final Exam)**
    - **9 am to noon, in RC 2003**
    - **Covers post-midterm material and related field trips;**

Source: Dearden and Mitchell (2012)

- Today:
  - (lecture)
    - Part 1: Human Interventions in the Hydrological Cycle
    - Break:
    - Map Literacy (ML.4) – June 5th
    - Part 2: Water Quality
    - Part 3: Water as Hazard

Part 1: Human Interventions in the Hydrological Cycle

- Key components of the hydrological cycle
- Water diversions, with examples
  - {dams: WAC Bennett; Old Man River; La Grande; Columbia River; Revelstoke Dam}
  - {floodways: Winnipeg; Neebing-McIntyre}
  - {inter-basin transfers: Kemano; Nechako River}

- Canada
  - only 0.5% of the world's population
  - Home to almost 20% of the global stock of fresh water;
  - Only 7% of total flow of renewable water (Brazil and Russia have more)
  - 2nd amongst water consumers in the world

From: Dearden and Mitchell (2012)

Hydrological Cycle

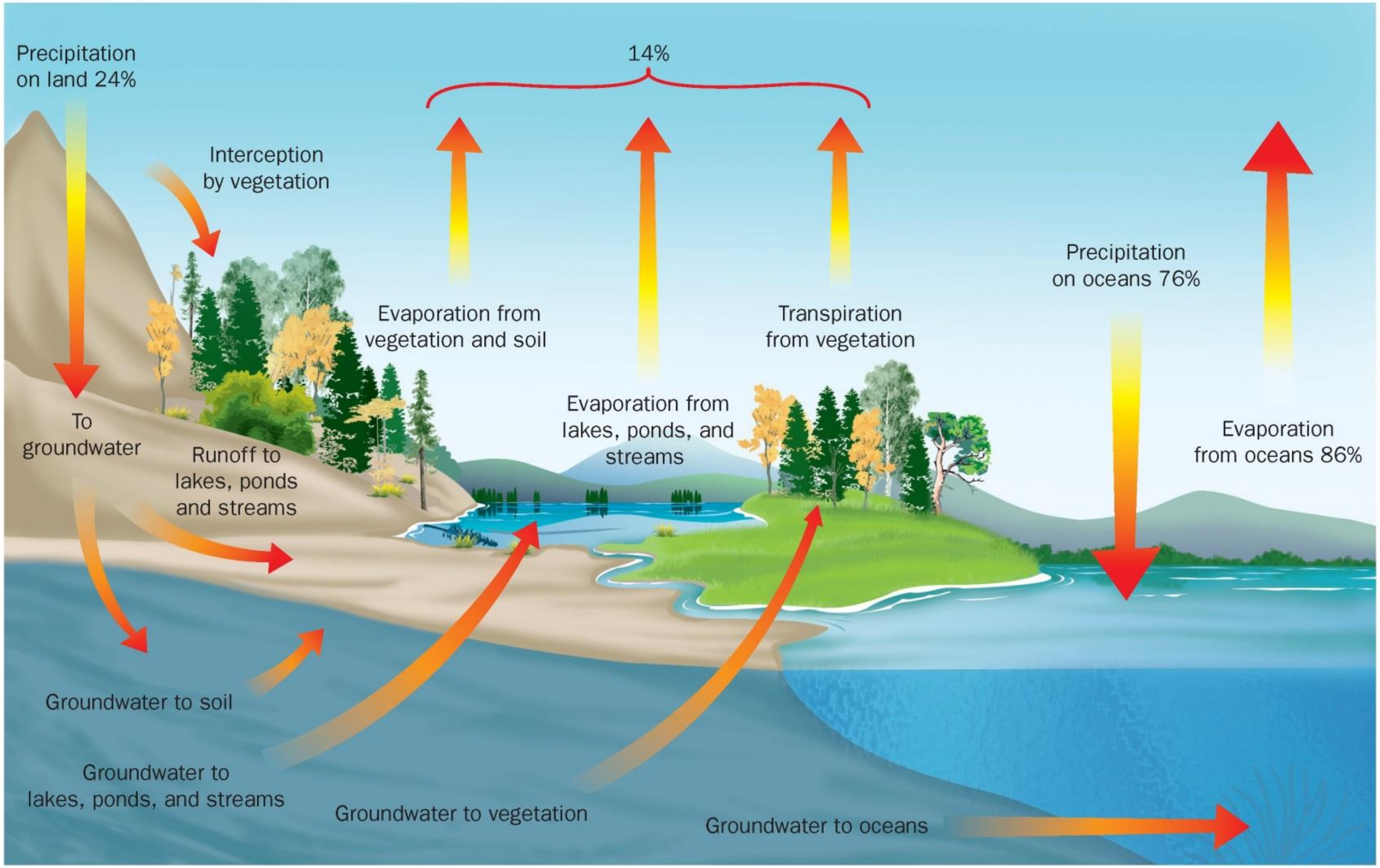


Figure 4.8 | The hydrological cycle. Water moves through the hydrological cycle as a liquid, as a vapour, and as snow.

From: Dearden and Mitchell (2012)

- About 12% of Canada is covered by lakes and rivers
- Various types of **wetlands**, hybrid aquatic and terrestrial systems, cover 14% of Canada
- Groundwater is a key source of water for rivers and lakes

From: Dearden and Mitchell (2012)

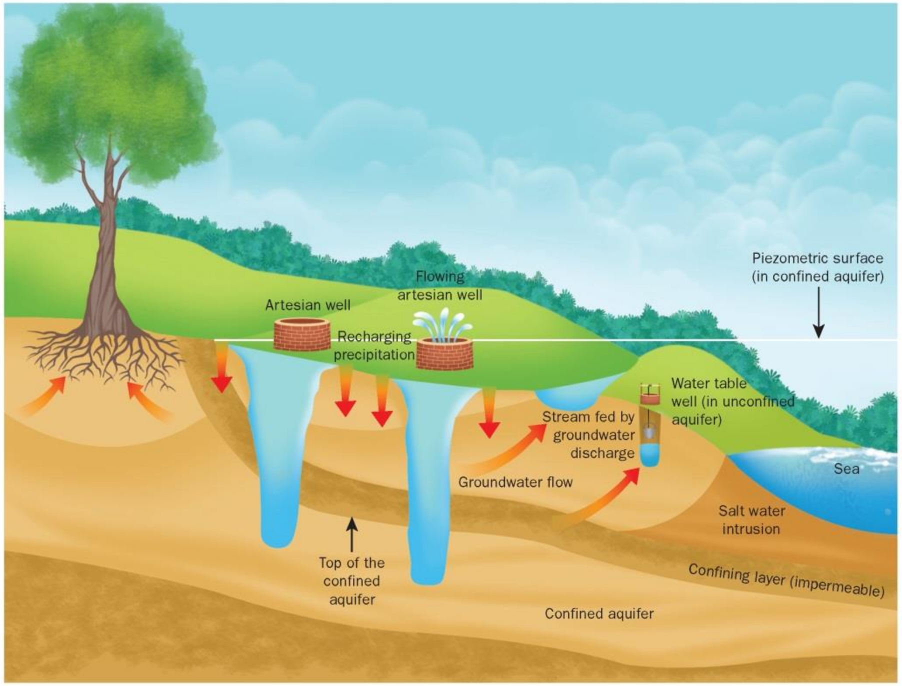
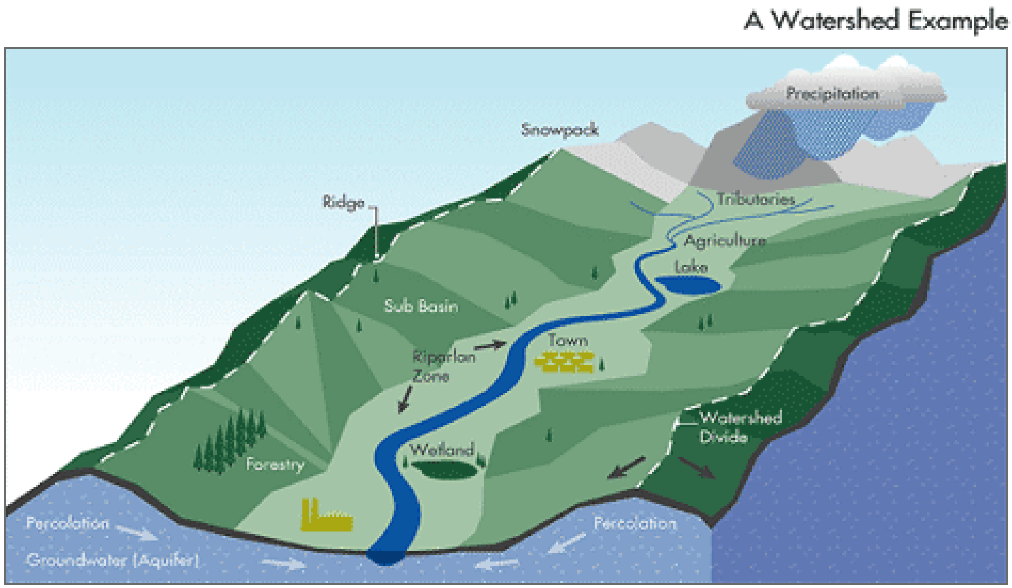


Figure 4.9 | Groundwater flow.



Terminology:

- Watershed;
- Drainage Divide or Divide;
- Floodplain

Water Diversion

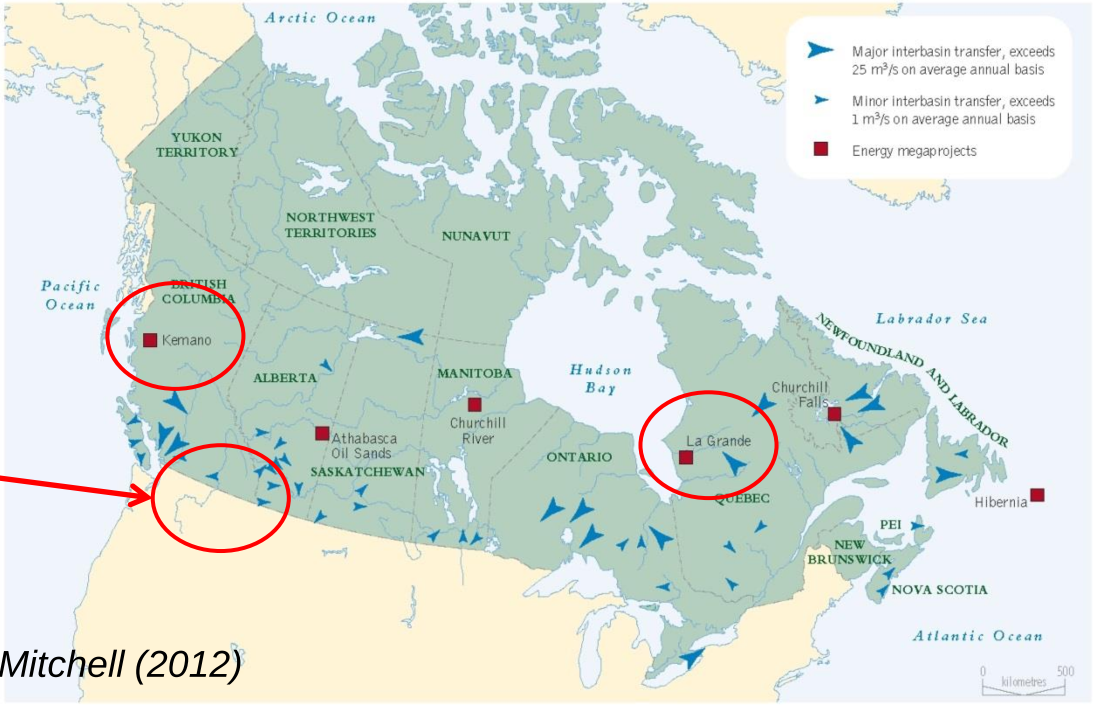
- **Dams**
  - (~900 large ones in Canada)
- **Inter-basin diversions**
  - (~60 large ones in Canada)

~333 (Quebec)

~149 (Ontario)

~131 (British Columbia)

Columbia



From: Dearden and Mitchell (2012)

Figure 11.1 | Hydroelectric megaprojects in Canada. *Source: Adapted from Day and Quinn (1992: 16).*

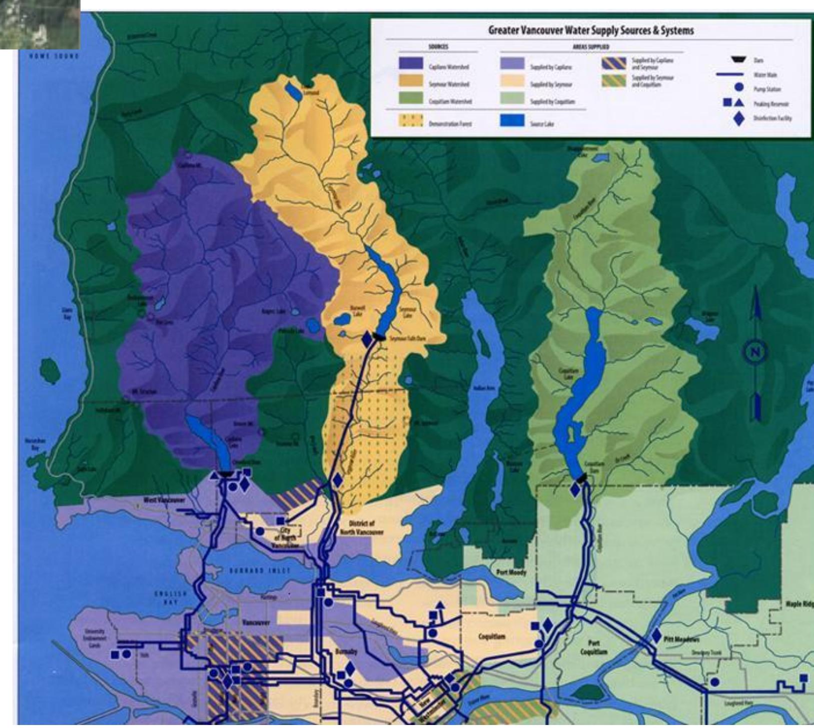
Reasons for Water Diversions (1)

- To increase community water supplies (for consumption, for irrigation … *less common in Canada than elsewhere*)
- e.g., Old Man R. dam (S. Alberta) (installed in 1992, response to droughts); Vancouver's three north shore watersheds

Old Man River dam.

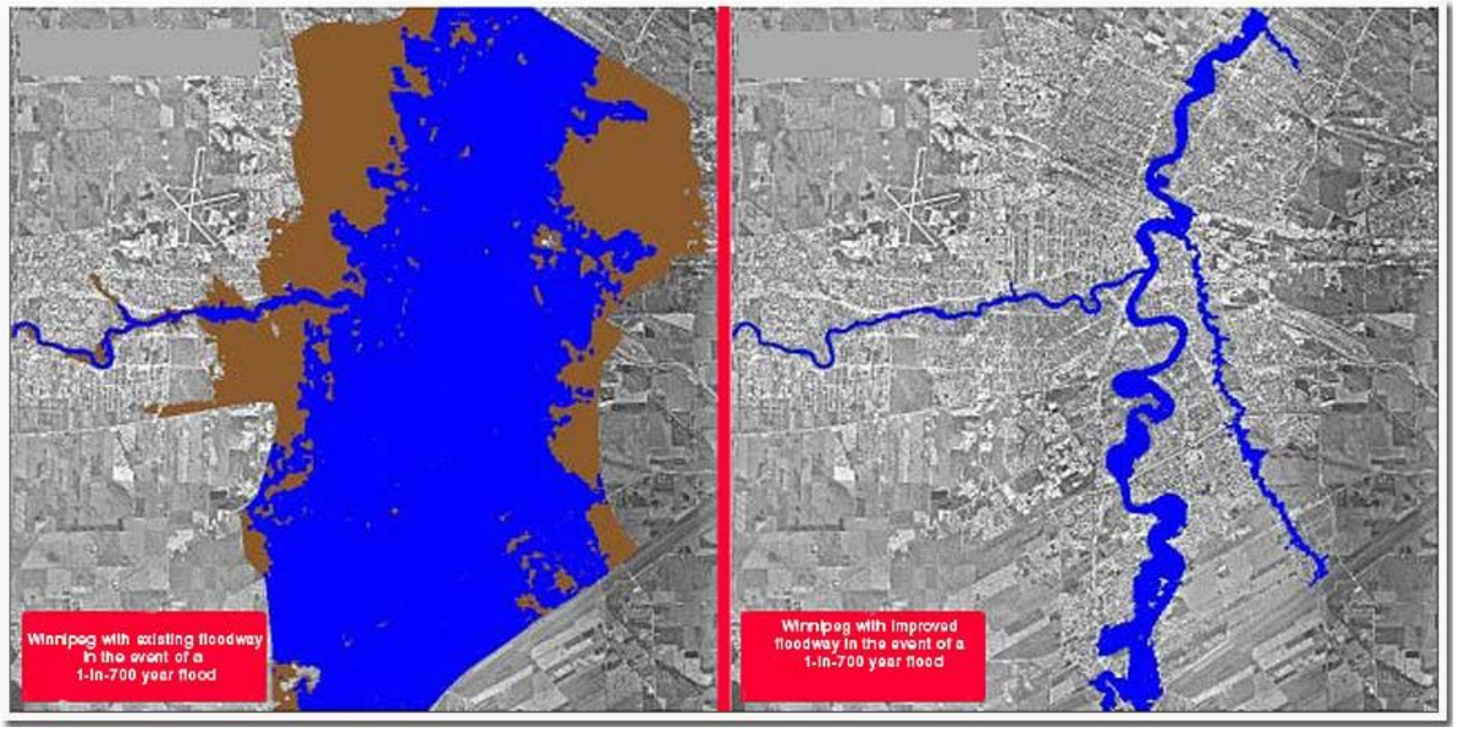
Capilano Reservoir


Capilano Watershed
Seymour Watershed
Coquitlam Watershed
Lower Seymour Conservation Reserve


Greater Vancouver Water Supply Sources & Systems
SOURCES
AREAS SUPPLIED
Capilano Watershed
Seymour Watershed
Coquitlam Watershed
Demonstration Forest
Supplied by Capilano
Supplied by Seymour
Supplied by Coquitlam
Source Lake
Supplied by Capilano and Seymour
Supplied by Seymour and Coquitlam
Dam
Water Main
Pump Station
Peaking Reservoir
Disinfection Facility
West Vancouver
District of North Vancouver
Vancouver
Burnaby
Port Moody
Coquitlam
Port Coquitlam
Pitt Meadows
Maple Ridge

Reasons for Water Diversions (2)

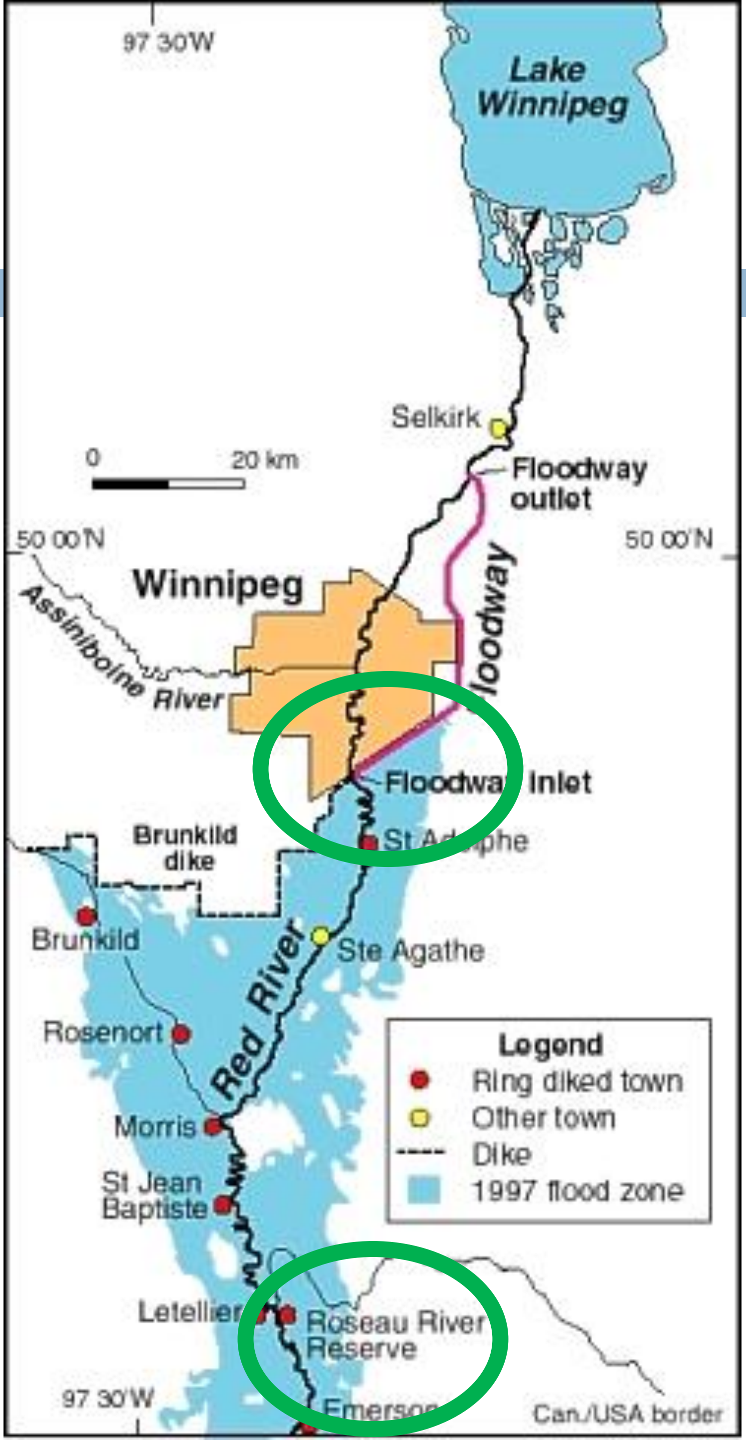
- To protect communities/infrastructure (flood protection)
- e.g. Winnipeg Floodway (shown during 1997 floods)



Potential impact of 700 year flood on Winnipeg without the floodway (left).
Source: Natural Resources Canada

Red River Floodway

- Significantly abated the 1996 and 1997 flood events



Winnipeg spillway – inlet; in operation during 1997 flood

Extensive flooding near Roseau River Reserve

Neebing River Spillway (Thunder Bay)

- Completed in 1982
- To carry floodwaters from Neebing R. to Neebing-McIntyre Diversion
- Dam at Lake Tamblyn part of “catchment control measures”
- To protect Intercity area

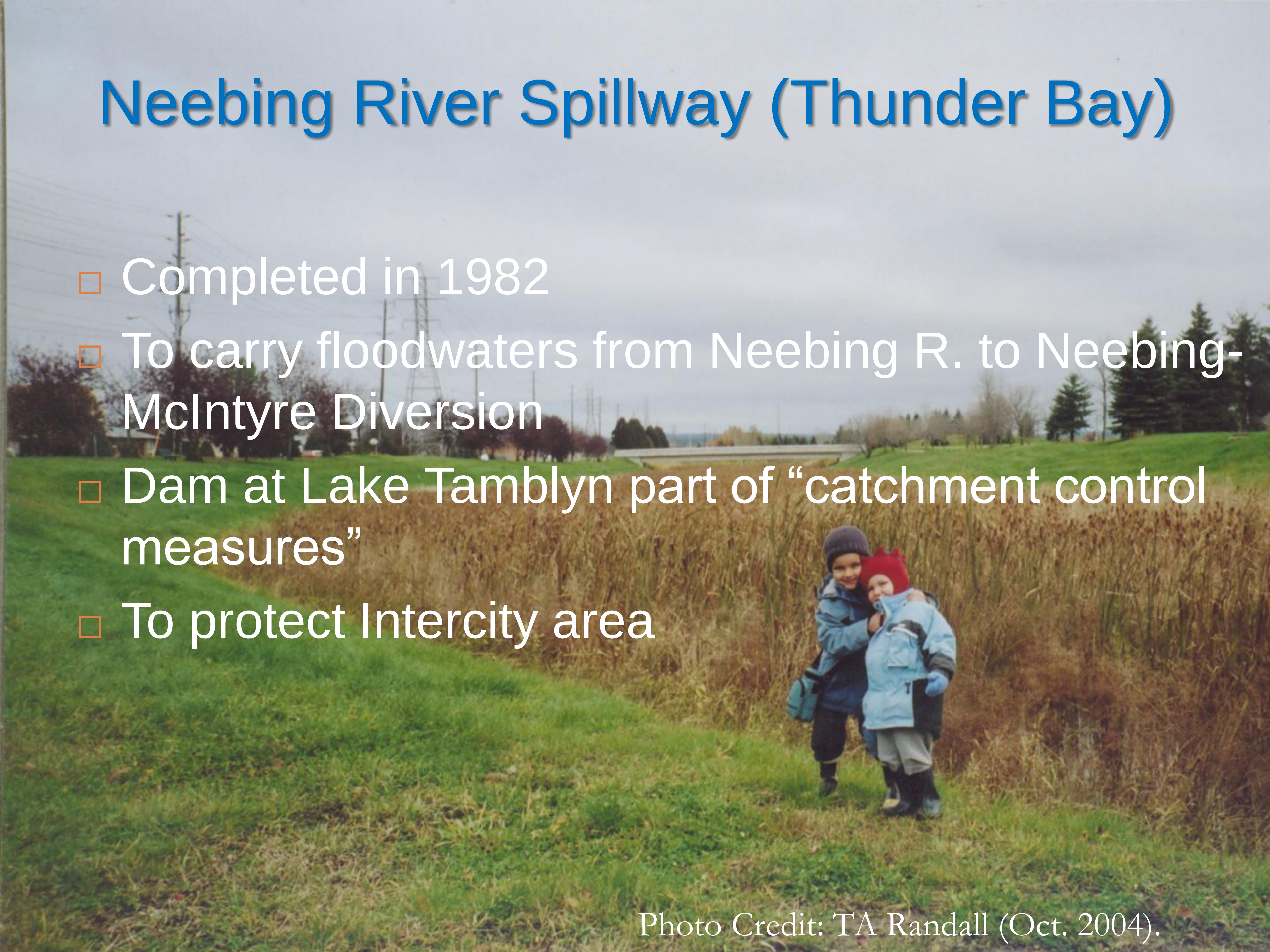
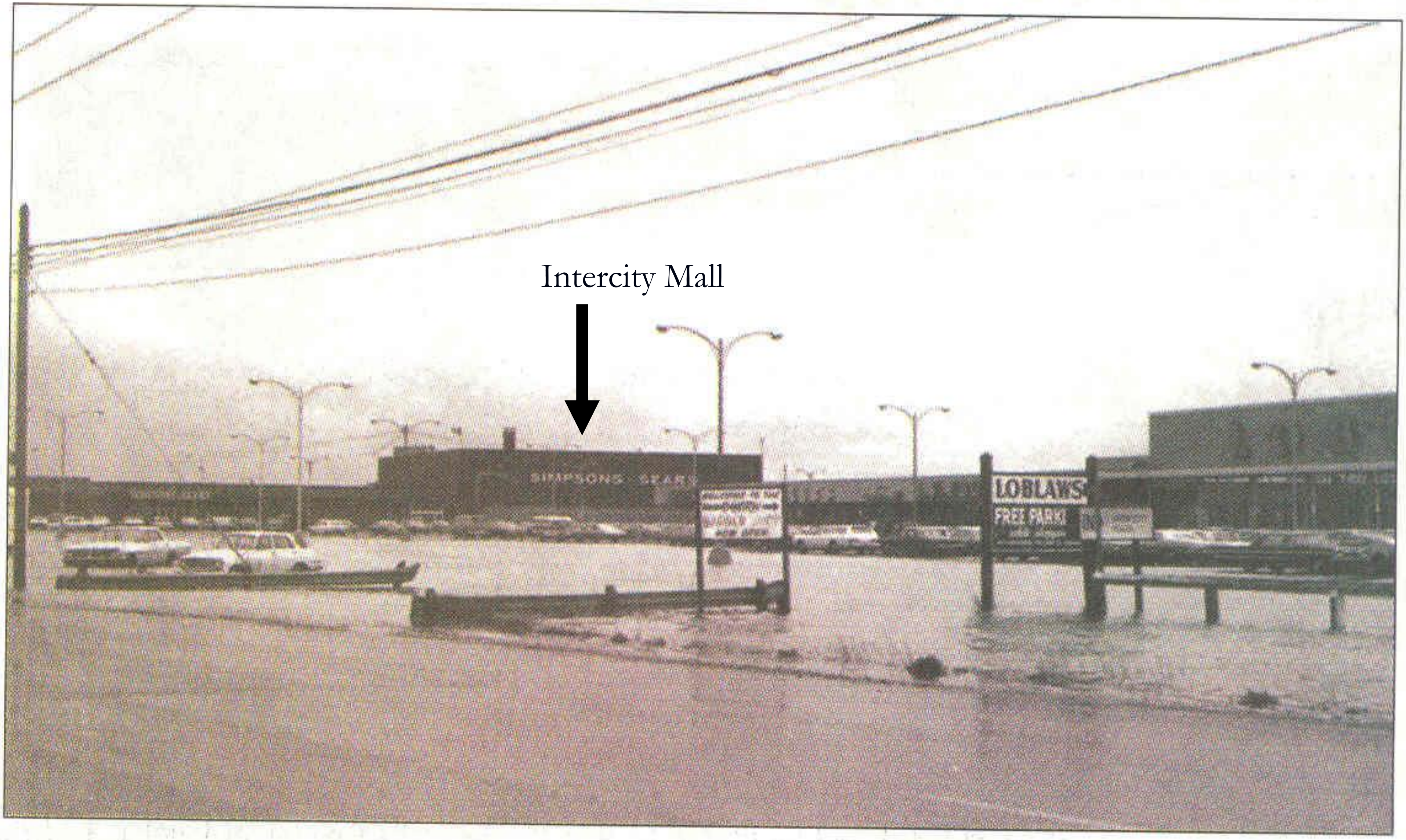


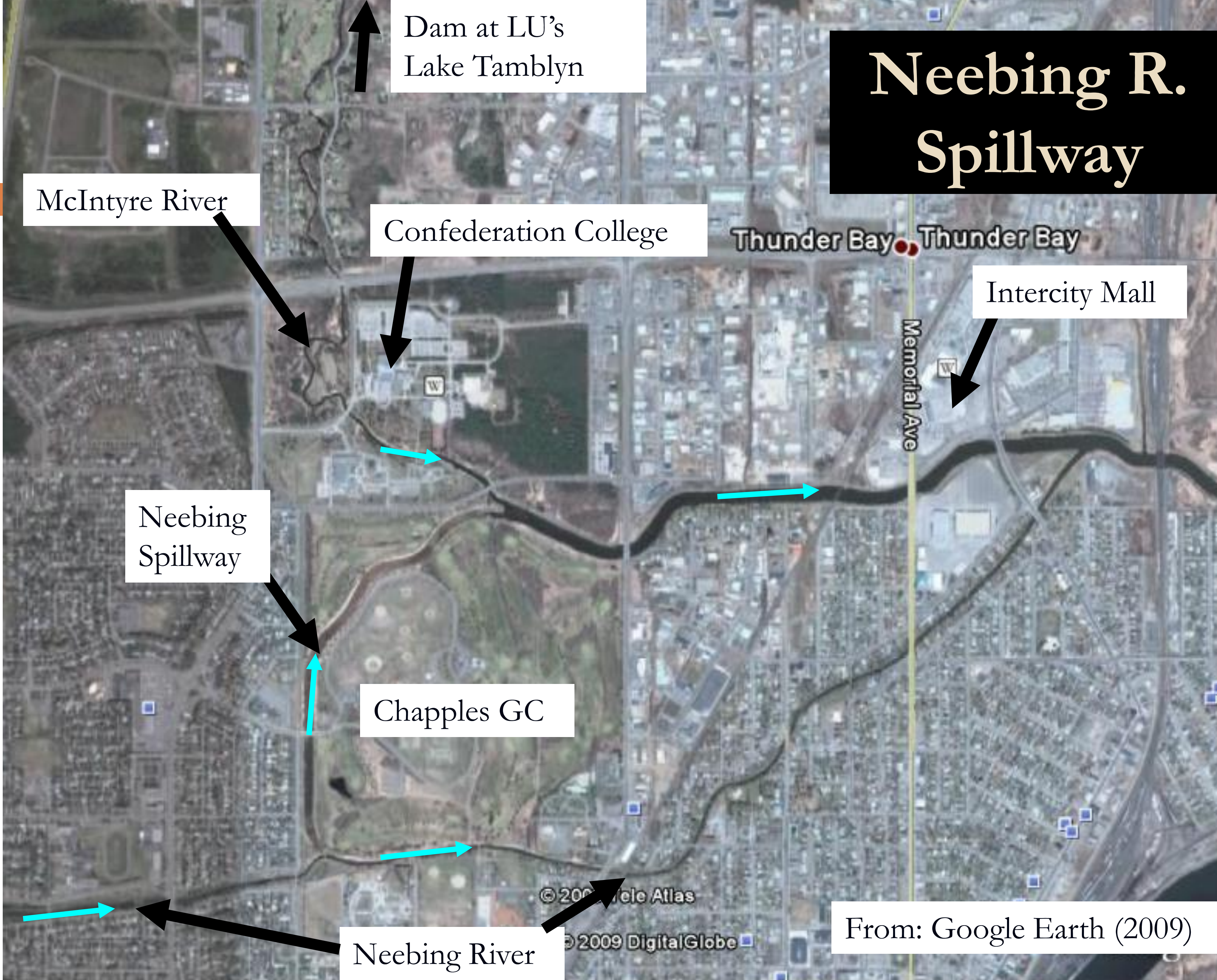
Photo Credit: TA Randall (Oct. 2004).



...a time before there was a Neebing - McIntyre Floodway?

From: Lakehead Region Conservation Authority (2005)

Neebing R. Spillway



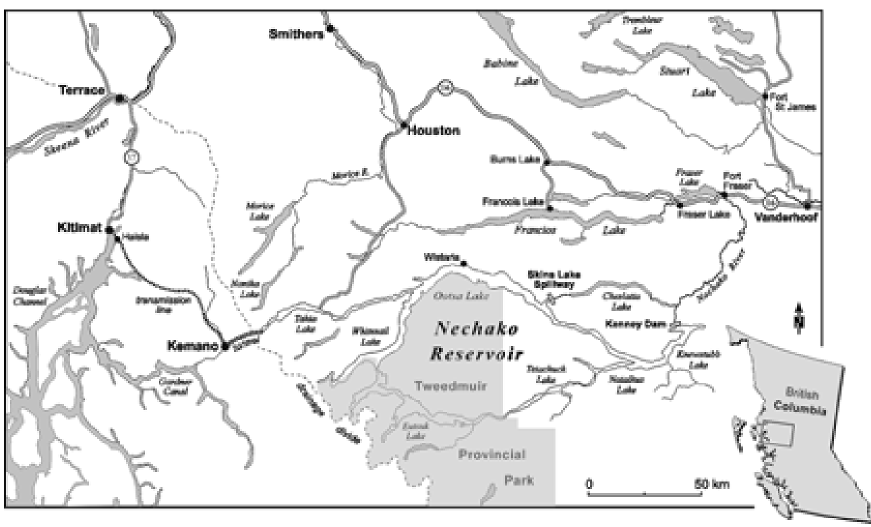
Reasons for Water Diversions (3)

- To augment/increase river capacity (for shipping, for moving goods downriver)
- e.g., small dams on Ottawa river to move logs to sawmills

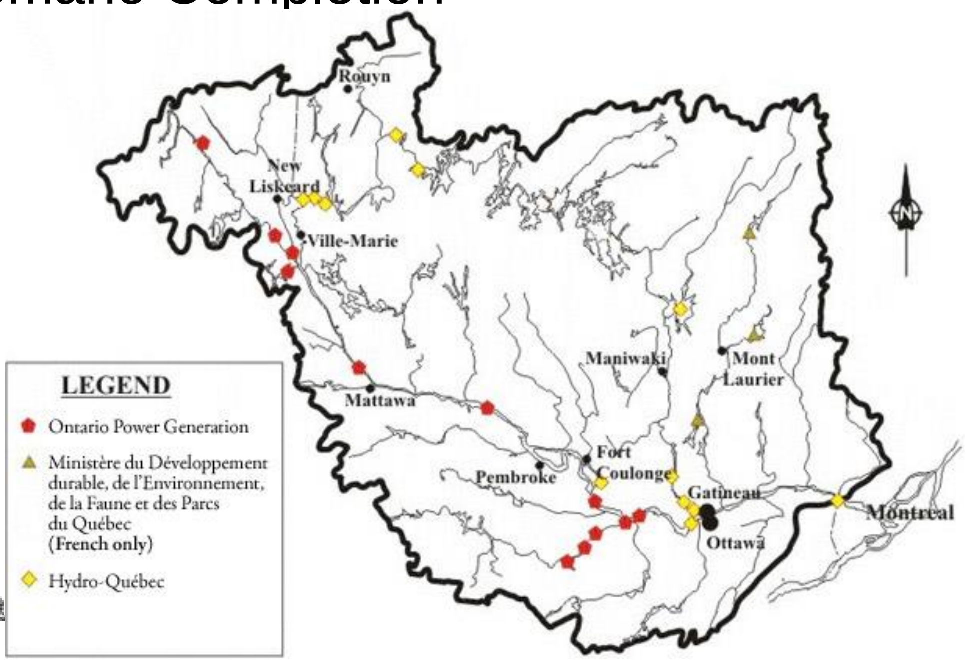
Timber rafts at Parliament Hill (in 1882)

Reasons for Water Diversions (4)

- To concentrate/consolidate water flows (for hydroelectric generation purposes)
- Canada a global leader in diversions for these purposes
- e.gs., Columbia River Treaty; James Bay Project; Churchill Falls; Gardner Dam, SK; Kemano Completion



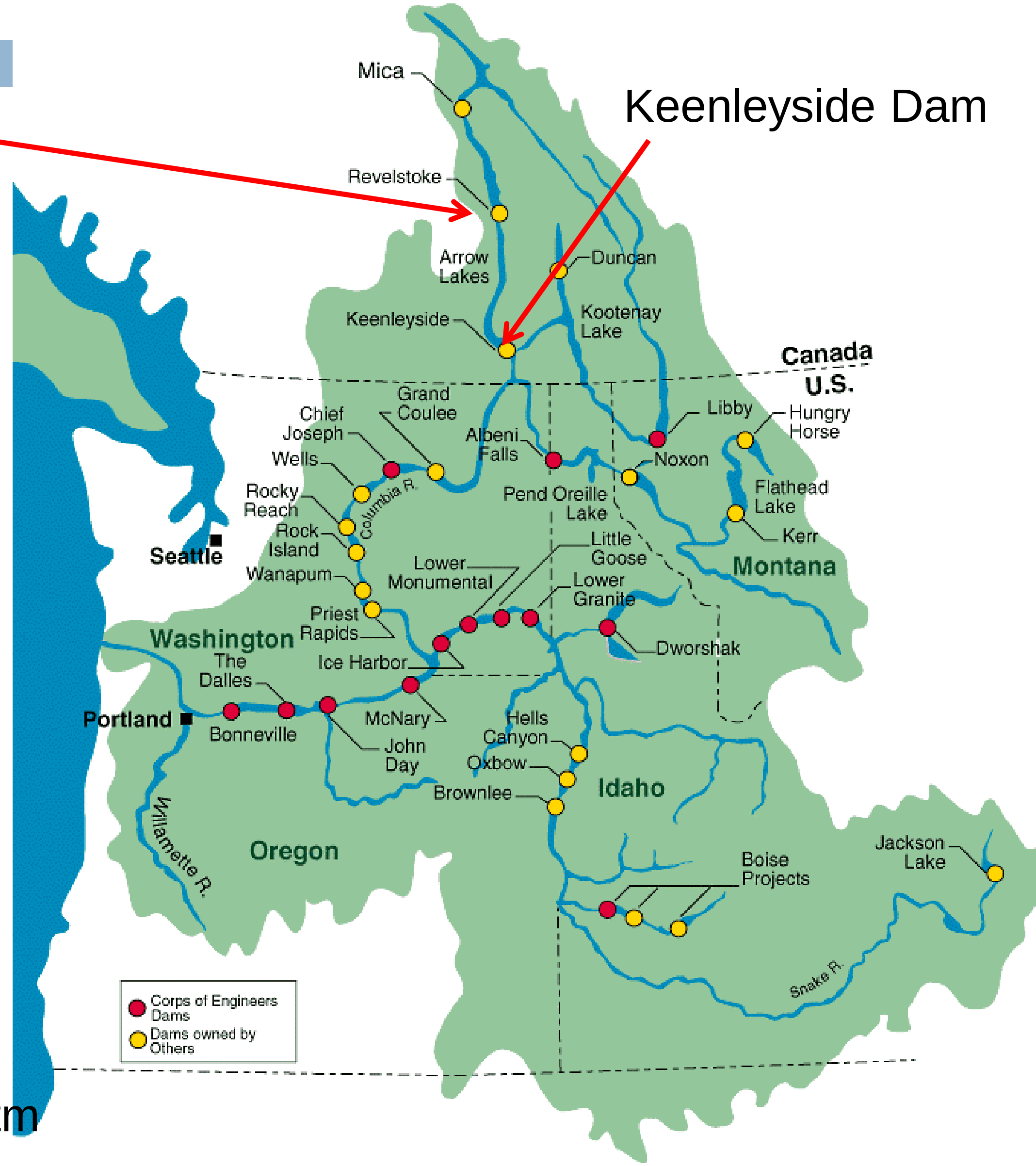
Kemano diversion (Nechako R. → Fraser R.)



Power generation in Ottawa River watershed

Columbia River Treaty (Can-US)

Revelstoke Dam, completed 1984 but NOT part of Columbia River Treaty dams



http://www.nwd-wc.usace.army.mil/report/colmap.htm

Columbia River Treaty (Can-US)

- Agreement 1964, re development and operation of dams in the upper Columbia basin for purposes of flood control and power generation;
- 4 dams constructed under this treaty (3 in Canada, 1 in US);
- The Canadian treaty dams (except the Mica) were initially for water storage and discharge regulation only;
- Canada is compensated financially for providing these storage and floor control benefits to downstream States;
- Treaty has no expiration, however at 60 years (in 2024), either country can terminate most provisions given a full 10 years notice (…. Currently both governments are reviewing as 2014 is 10 years requirement of notification….)

Columbia River Treaty (Can-US)

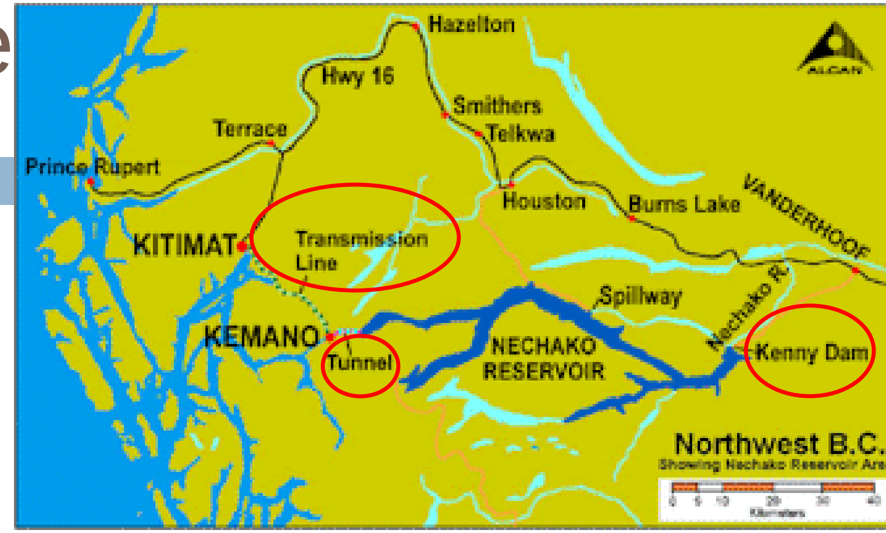
- Advantages
  - Economic benefits to both BC and Pacific NW states (including but not limited to employment);
  - Flood control
- Disadvantages
  - Social impacts: community and home relocations; loss of culturally significant First Nations landscapes (including burial grounds) of the Sinixt people who occupied the Columbia Valley;
  - Environmental impacts: during both construction and operation phases; “loss of natural river behaviour” (e.g., smoothing of annual hydrograph – lower peak flows, higher winter ‘low’ flows) (reduced peak levels by 10’s of metres); impacts on fish habitat (water temperature, sedimentation) and fish migration;

Hugh Keenleyside Dam, completed in 1968

Hugh Keenleyside Dam and Arrow Lakes Reservoir
Interactive Pre- and Post-Dam Image: Burton


Other images viewable at:
http://www.cbt.org/crt/resources-PreAndPostImages.html

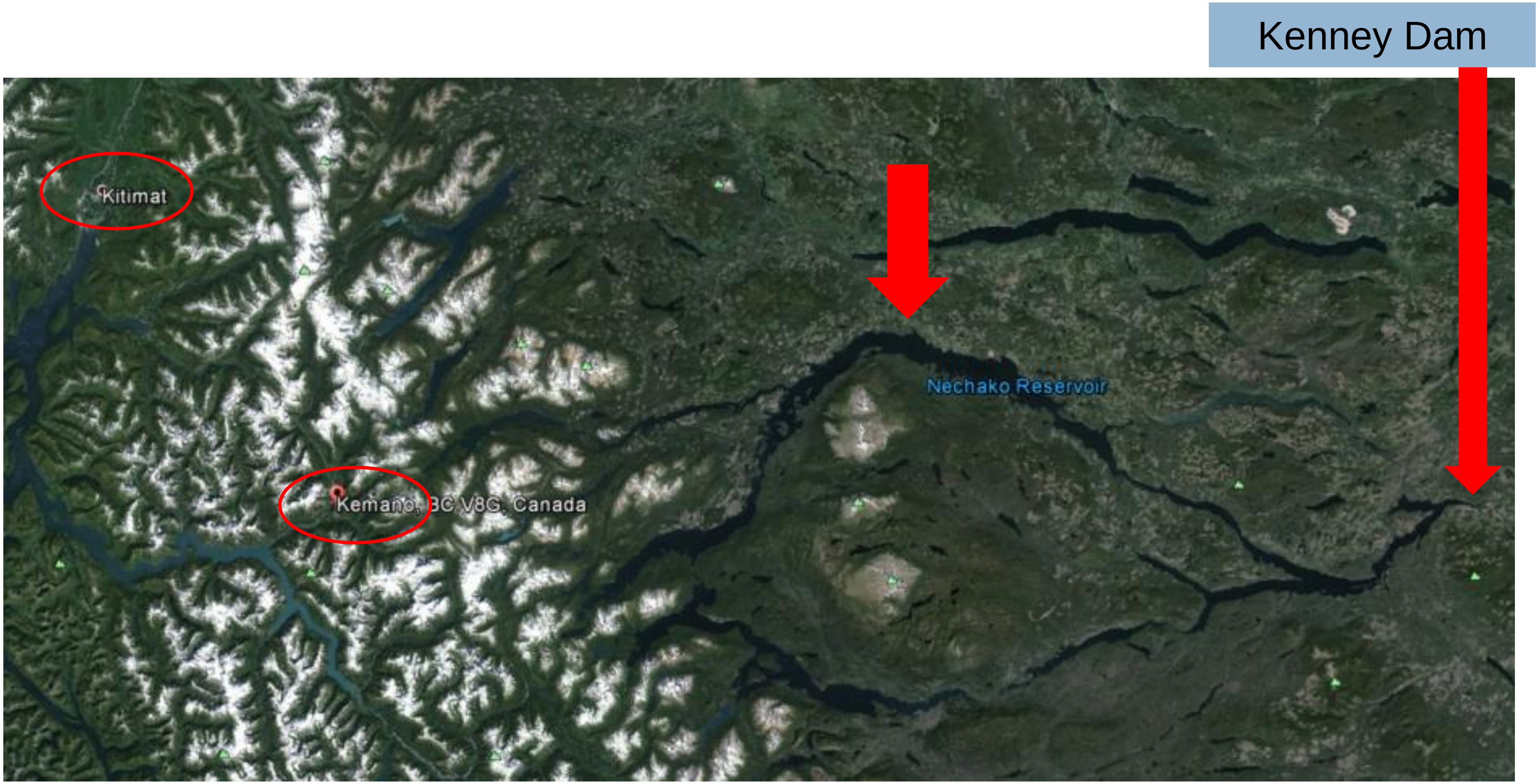
Kitimat-Kemano Proje



- 1948: BC Gov't invited Alcan to consider building aluminum smelter on BC Coast;
- Dec. 1950: BC Govt granted Alcan license to divert water from Nechako and Ninika watersheds to feed turbines at Kemano hydro-station;
- First Nations situated on reserves on Lake Cheslatta (which would be inundated by the rising Nechako Reservoir) were relocated – with very little notice – April 1952;
- Kenney Dam completed in Oct 1952

www.kitimatmuseum.c

Nechako Reservoir – Ootsa Lake



Source: Google Earth 2014

- Flows in upper Nechako dropped to 25% of normal for 4 years after dam completion (to fill reservoir)
- Chinook salmon run all but destroyed during this period
- 1957: Smelter at Kitimat in full operation, powered by "Kemano 1"
- Late 1970's interest in Kemano 2 ("Kemano Completion Project") – has been subject of much debate during 1980s-1990s at times being approved by Fed Govt (e.g., exempted from an Environmental Assessment in 1991 by Mulrooney Govt); it has yet to be built
- Kemano plant is now largely automated, with the community of Kemano formally closed in 2000;
- Dislocated FN still active ….

Cheslatta aboriginals seek Kenney Dam water licence

An aboriginal band in north-central B.C. has moved toward harnessing the power of a hydro-electric dam that flooded their territory and imprinted images of floating coffins into their history.

Sixty-two years after the Kenney Dam flooded the traditional territory of the Cheslatta Carrier Nation, destroying hunting, fishing and living areas and drying up parts of the Nechako River, the Prince George-area nation plans to profit from the structure built without their consultation to power the Rio Tinto Alcan smelter in Kitimat.

Source: The Globe and Mail, Monday September, 30, 2013

James Bay Project

From: Dearden and Mitchell (2012)

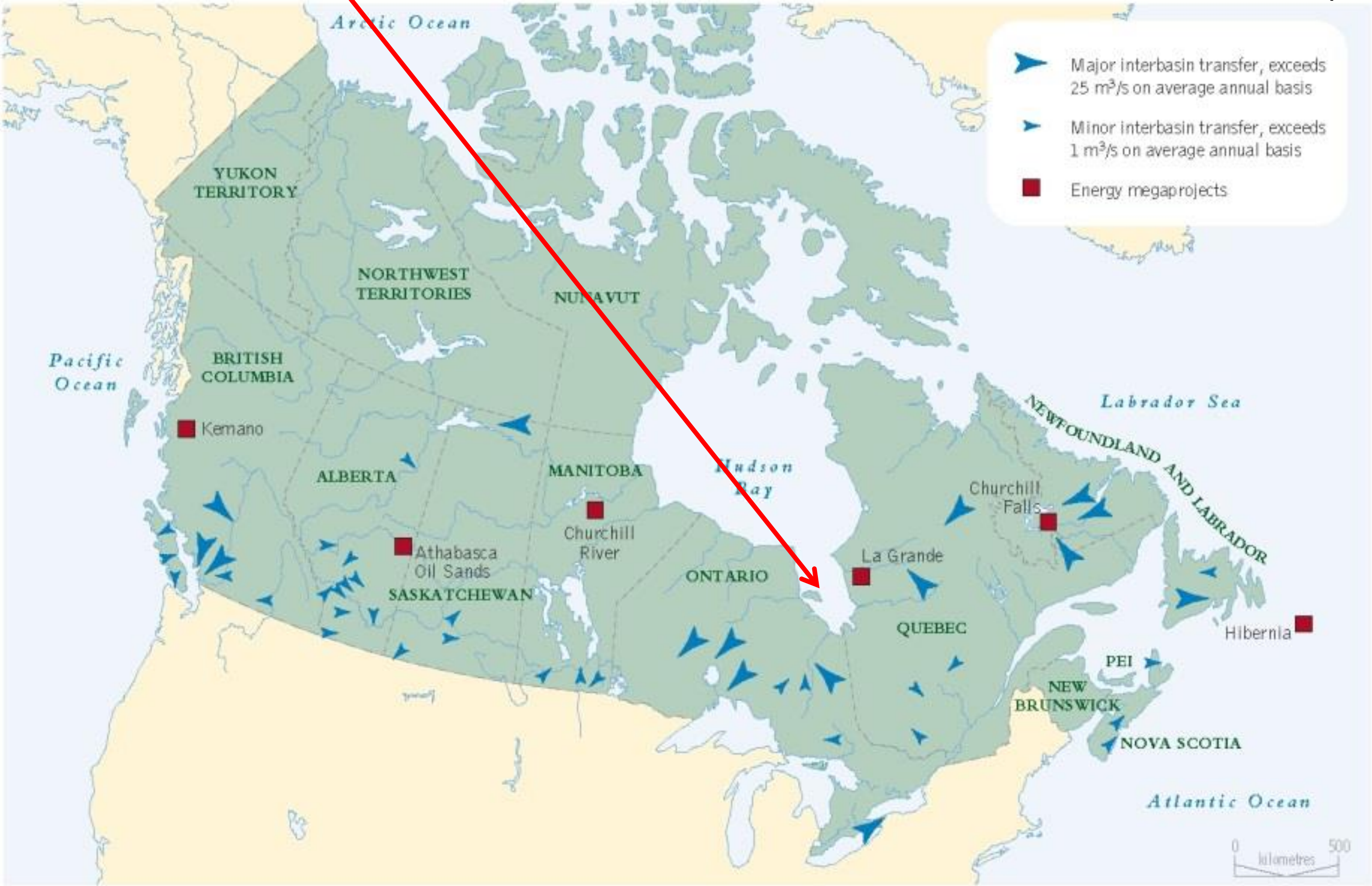


Figure 11.1 | Hydroelectric megaprojects in Canada. *Source: Adapted from Day and Quinn (1992: 16).*

La Grande River (James Bay Pr. Phase I)

- Part of hydro development originally proposed in 1971 to satisfy future electricity needs in Quebec;
- **Phase I: La Grande River**
  - Flow to this basin doubled via diversions from adjacent watersheds;
  - LG2, 3 and 4 constructed; LG1 deferred to Phase II;
  - Phase I completed in 1986
- **Phase II: announced 1985**
  - Energy for export to US;
  - Energy (low cost) to attract energy-intensive industries to PQ

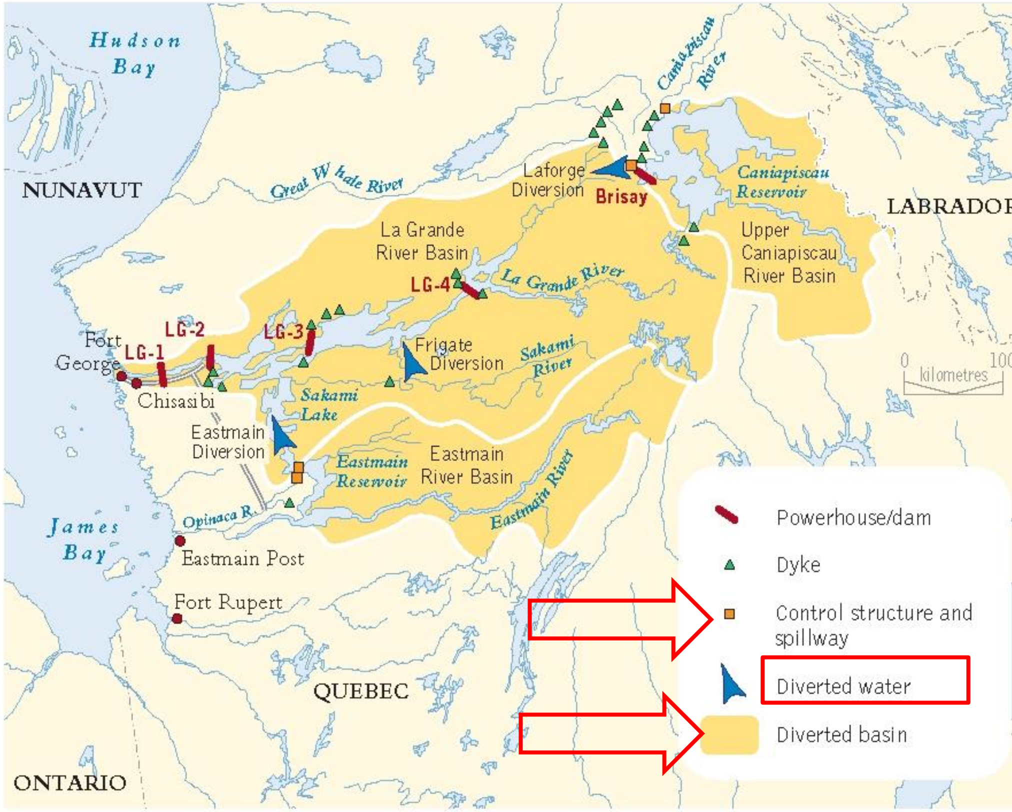


Figure 11.2 | La Grande River hydroelectric development project, Phase 1. *Source: D and Quinn (1992: 134).*

From: Dearden and Mitchell (2012)

James Bay Pr. Phase II (Great Whale Project)

- Like Phase I, continues to encroach on traditional territory of >10,000 Cree and Inuit;
- Encompasses an area ~size of France
- An agreement was reached "James Bay and Northern Quebec Agreement" in 1975 – between govts and these First Nations (the first '*modern*' land claims agreement)
- Agreement included provisions for: 1) land rights; 2) a process to deal with future hydro developments

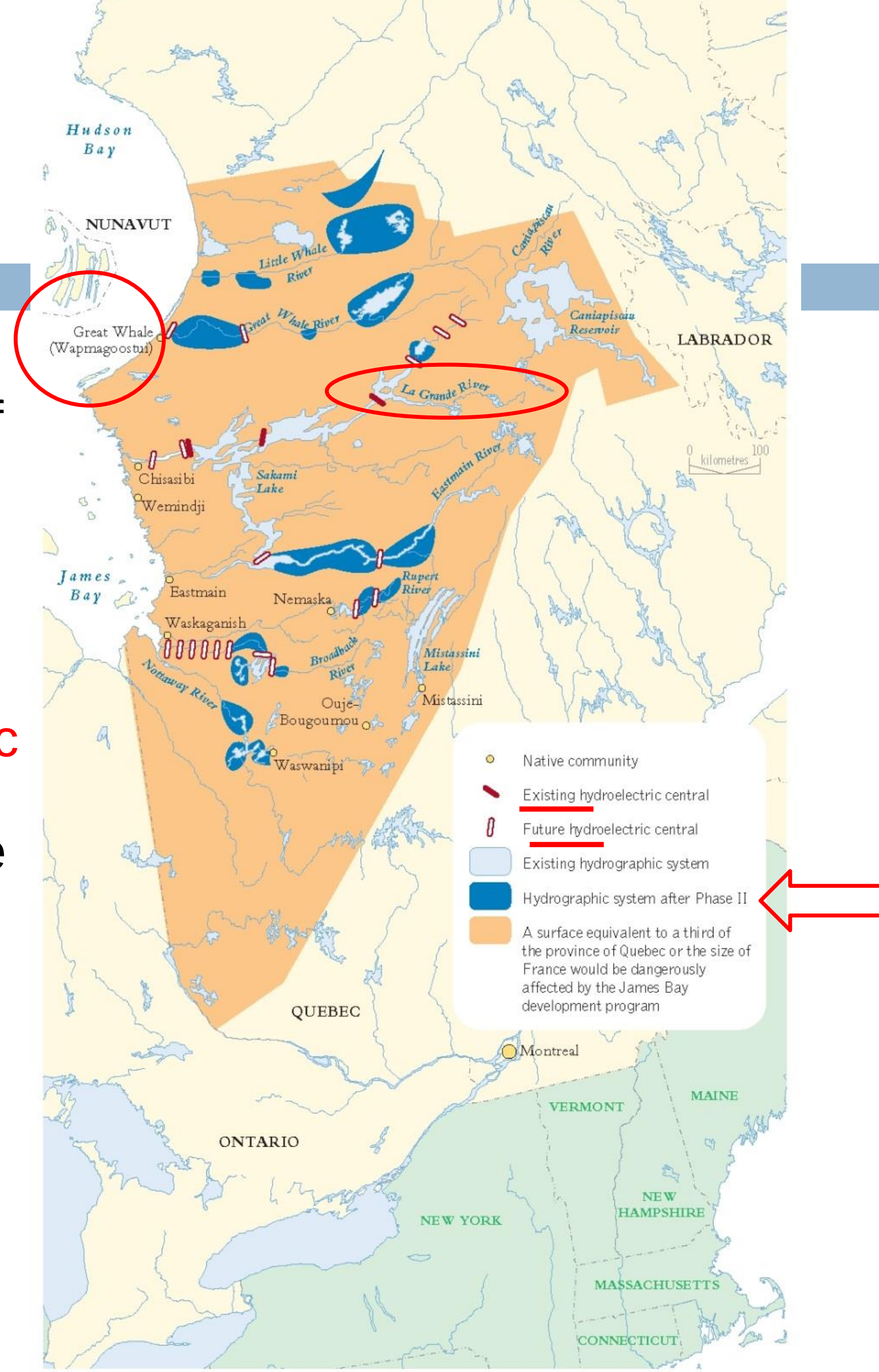


Figure 11.3 | The Great Whale project. *Source: Diamond (1990: 32).*

Need for adaptive management approach …

- … reinforced by concerns / issues raised during construction period and in years following const

- **<u>During Construction:</u>**
  - Relocation of Ft George to new site at Chisasibi;
  - Quality of drinking water at new community;
  - Problems maintaining traditional hunting activities (affected due to access road construction, altered patterns of ice breakup by release of 'warm' water from reservoirs)

- **<u>Following Construction:</u>**
  - Very high levels of Mercury in fish caught in reservoirs or connecting rivers;

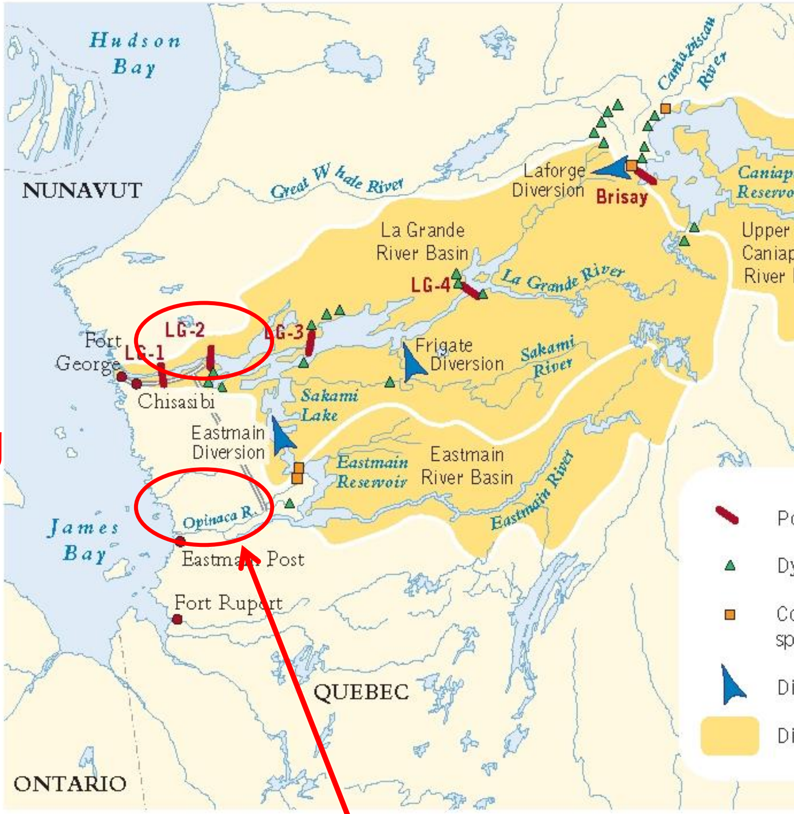


Figure 11.2 | La Grande River hydroelectric development project,
and Quinn (1992: 134).

Opinaca R.

- No environmental assessment had predicted the appearance of Hg in reservoir fish;
- Monitoring ongoing for both fisl and higher consumers (e.g., Cree populations);
- Some improvements (i.e., drop in Hg levels in Cree) but these may be due to change in diet rather than change in concentrations in fish species they used to consume; (from studies in late 1990s')

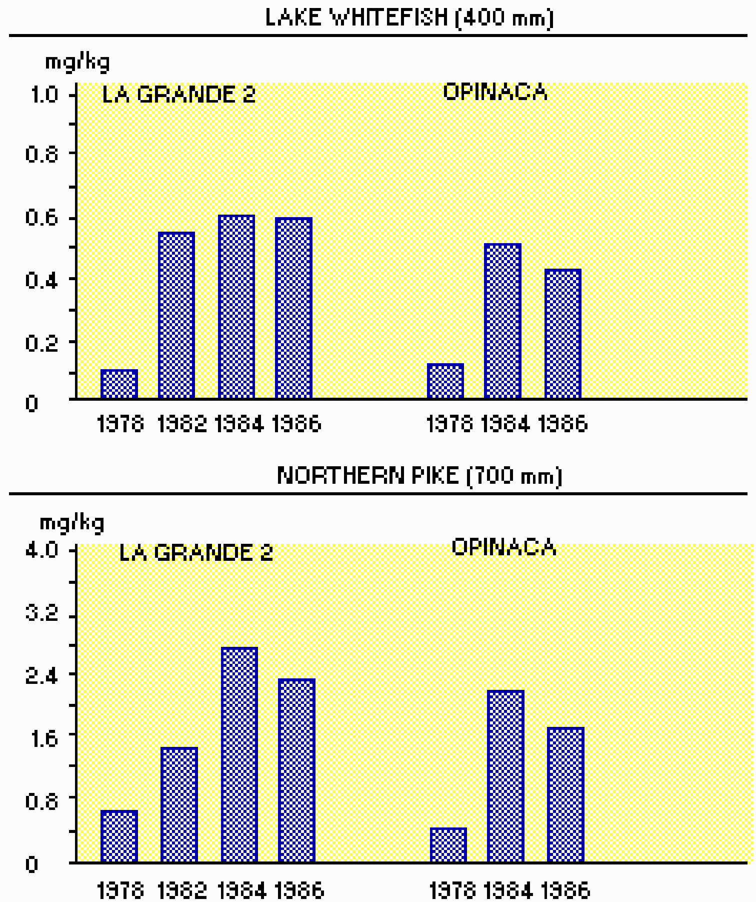
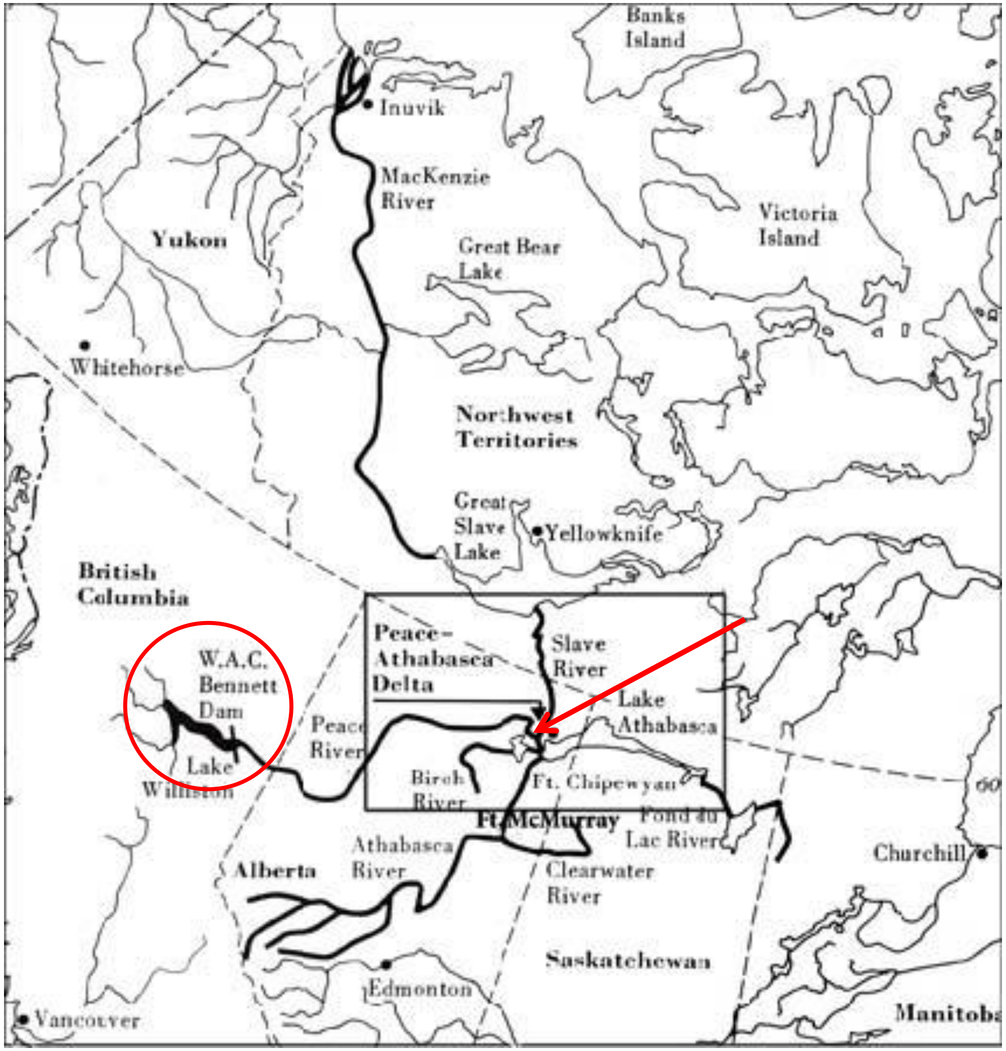


Fig. NAM-28-12 Average mercury levels [mg kg^{-1}] in the flesh of lake whitefish and northern pike in the La Grande 2 and Opinaca Reservoirs (11).

Fig. NAM-28-12
(11) Average mercury levels [mg kg-1] in the flesh of lake whitefish and northern pike in the La Grande 2 and Opinaca Reservoirs.

http://wldb.ilec.or.jp/data/databook_html/nam/nam-28.html

WAC Bennett Dam, Peace River, BC



- Built in 1967
- Created Lake Williston
- **Significant downstream impacts** on river hydrology (magnitude and timing of discharge) and on riverine habitats (especially the Peace-Athabasca delta) and the loss of 'regular flooding' in that ecosystem

References

- Dearden, P and Mitchell, B. 2012. *Environmental Change and Challenge*, Fourth Edition, Don Mills, Ontario: Oxford University Press {Chapter 11: ‘Water’}

Part 2: Water Quality and Water as Hazard

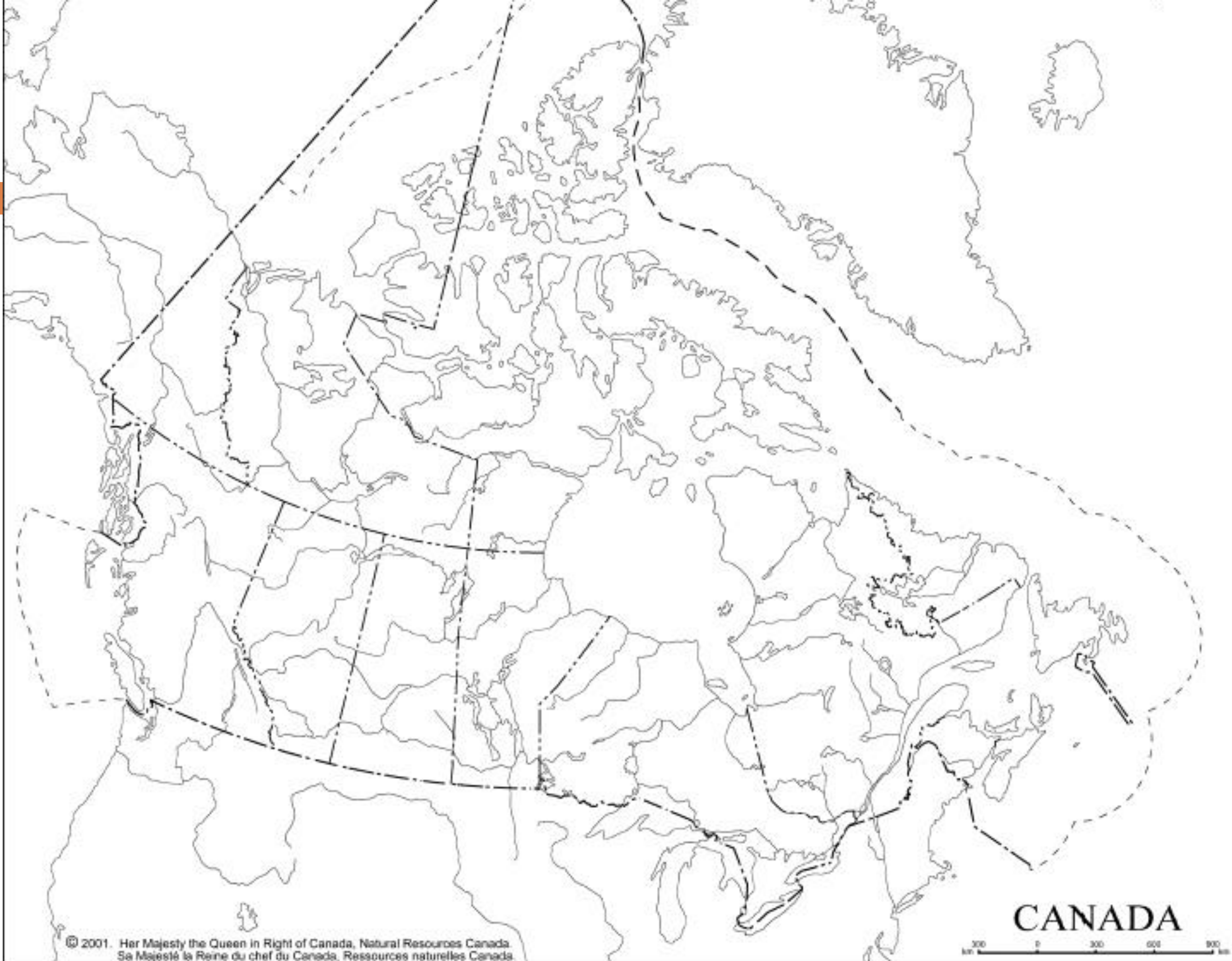
- *<u>Activity:</u>* Map Literacy List #4
- Water Quality
  - Monitoring by Environment Canada in partnership with other jurisdictions;
  - Point / Non-point pollution sources
  - Great Lakes
- Water Security
  - Walkerton and subsequent inquiry

From: Bourdon and Mitchell (2012)

Map Literacy 4 (Spring 2014)

Lectures 17 to 20

June 7, 2014


CANADA
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Map Literacy (list 4, June 7, 2014)

Communities, Parks Jurisdictions

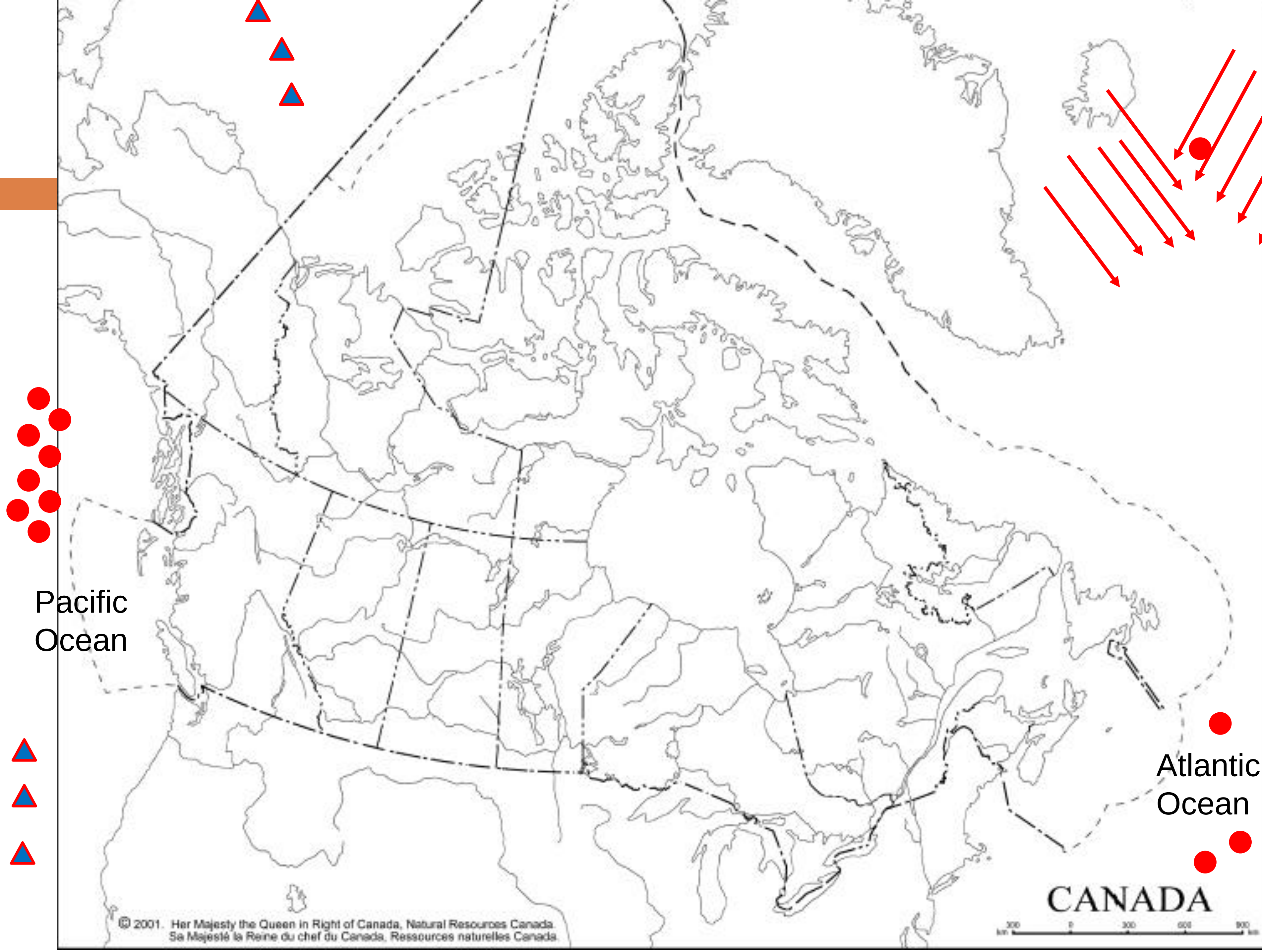
1. Walkerton, ON
2. Attawapiskat First Nation (FN)
3. Hamilton
4. Thunder Bay
5. Alaska
6. Jasper National Park
7. Banff National Park

Basics (1):

1. ….

Physical Features

1. La Grande River
2. St Lawrence River
3. James Bay
4. Columbia River
5. Fraser River
6. Red River
7. Great Slave Lake
8. Great Bear Lake


Pacific Ocean
Atlantic Ocean
CANADA
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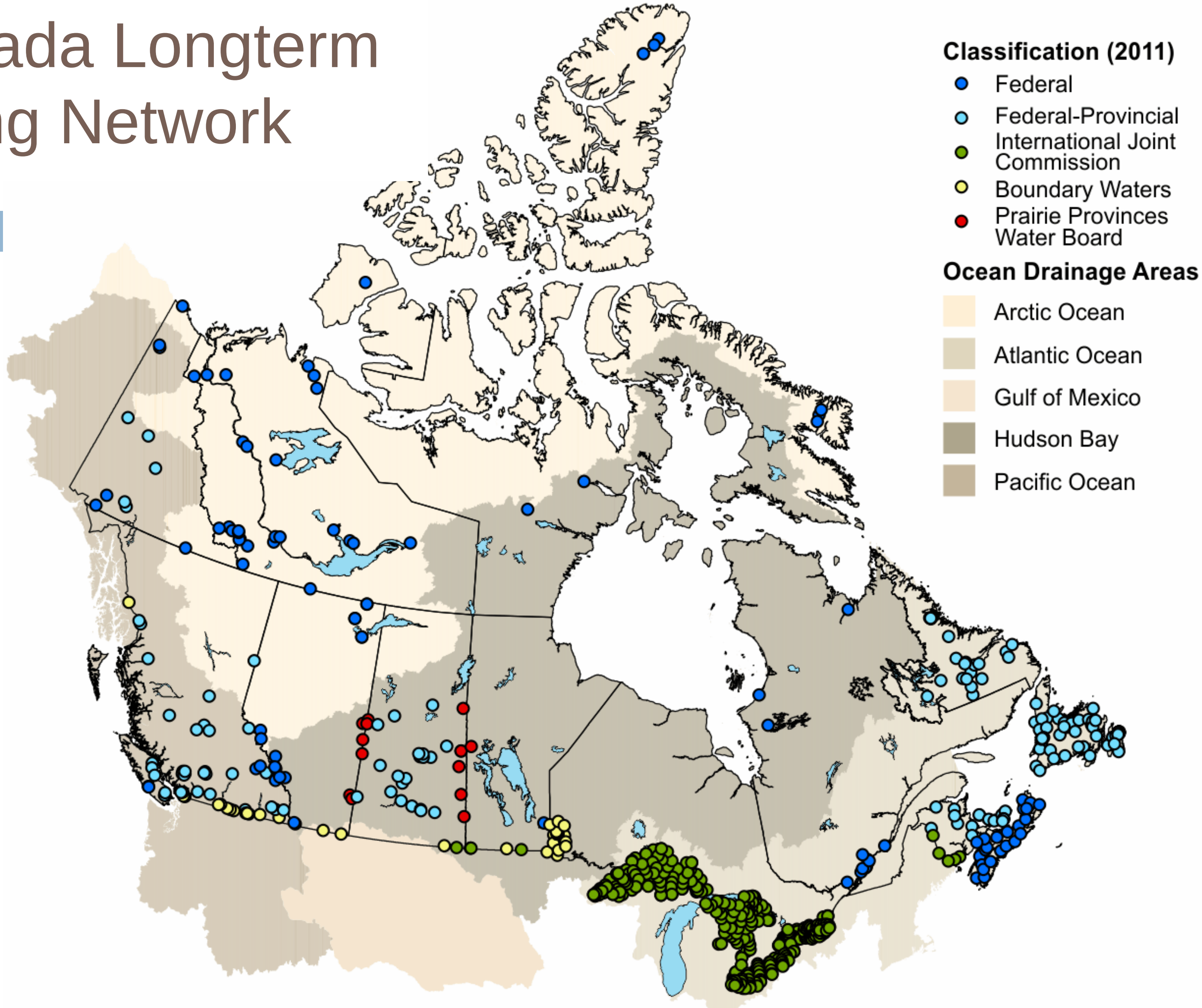
Water Quality Assessments

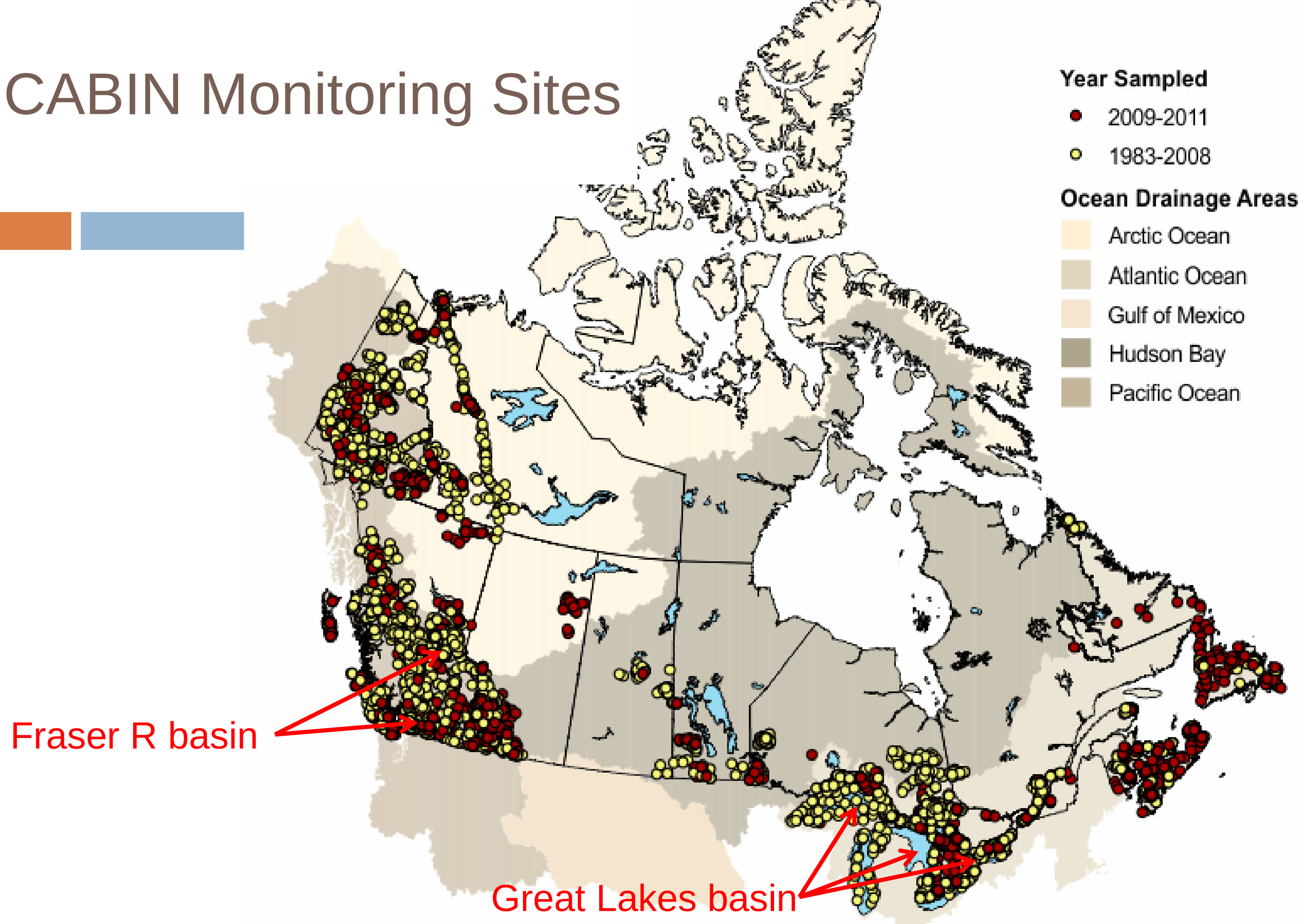
- Via Environment Canada's "*Freshwater Quality Monitoring program*"
- To assess and report on status/trends on the health of aquatic ecosystems, and "the ability of surface waters (rivers, lakes) to protect aquatic life"
- Water quality assessed at selected locations only…. a report in 2010 by Commission of Environment and Sustainable Development (issued by Office of the Auditor General) "*Environment Canada is **not adequately monitoring** the quality and quantity of Canada's surface water resources …*"

Env Canada Longterm Monitoring Network



Measurements regularly include physicochemical parameters such as temperature, pH, alkalinity, major ions, nutrients and metals. The network, intended specifically to supply water quality data in accordance with the Canada Water Act.

CABIN Monitoring Sites



Canadian Aquatic Biomonitoring Network (CABIN), integral part of national water quality monitoring network since 2006, incorporates biological information into traditional physicochemical water monitoring. – grew out of two early 90s pilot projects in the Great Lakes and in BC's Fraser River basin.

Water Quality (status in Canada, ~2006)

- Three key insights from EC (up to 2006)

1. Freshwater at 379 monitoring stations in *southern* Canada

2. Freshwater at 32 monitoring stations in *northern* Canada

Water Quality (status in Canada, ~2006)

- Three key insights from EC (up to 2006)

3. St Lawrence basin (including Great Lakes) – highest 'poor or marginal quality'

poor or marginal **28%**

while Maritime (Atlantic) and Arctic drainage basins have highest 'good' or 'excellent' quality

"good' or 'excellent' **71%**

Sources of Water Pollution

- main sources: Industrial, Urban Wastes (especially wastewater) and Agriculture
- **<u>point sources:</u>** e.g., manufacturing plants or sewage treatment plants
- **<u>non-point sources:</u>** e.g., agricultural and urban runoff; more difficult to identify since they cannot be associated with specific locations

End of pipe (point source) in Great Lakes basin from Dearden and Mitchell (2012)

Industrial point-source on Calumet R (Chicago) from Dearden and Mitchell (2012

Point Sources

- Urban wastewater receives varying levels of treatment in Canada (Primary, Secondary, Tertiary); **many sewage treatment facilities are old and require expensive maintenance, upgrading, or replacement ("deferred maintenance") .. much of what has not been done;**
  - **Primary treatment** removes insoluble material,
  - **Secondary** removes bacteria, and
  - **Tertiary** removes *some* chemicals and nutrients
- ** There are designated quality levels specified for wastewater treatment, conditional on the nature of the receiving body of water. (cf. Speed River at Guelph WWTP, ON vs. Hamilton WWTP on Lake Ontario)
- Industry is also an important source of wastes
- Runoff from urban areas either flows directly into water bodies from roads and other non-point sources, or can be channelled by stormwater systems

Point Sources

- Industry is also an important source of wastes
- Runoff from urban areas (Stormwater) either flows directly into water bodies from roads and other non-point sources, or can be channelled by stormwater systems

Photo courtesy of NOAA

Series of retention ponds along east side of TBRH structure. Fountains to reduce/prevent mosquito larvae. TBRH site (Fall 2004).

From: Google Earth (2009)

Industry point sources of pollution …

- most prevalent chemicals

Table 11.1 | Top Releases of Chemicals to Water, 2001

Chemical	Releases (tonnes)
Ammonia (total)*	26,106
Nitrate ion in solution at pH equal to or greater than 6.0	22,450
Manganese (and its compounds)	1,157
Methanol	697
Zinc (and its compounds)	308

*Total includes both ammonia (NH_3) and ammonium ion (NH_4+) in solution.

Source: Statistics Canada (2003b: 18).

From: Dearden and Mitchell (2012)

Industry point sources of pollution …

Table 11.2 | Water Bodies Receiving More Than 500 Tonnes of Pollutants, 2001

Water Body	Total Release (tonnes)	Dominant Release	Share of Total Release (%)
Fraser River	9,168	Ammonia*	49.2
Lake Ontario	8,877	Ammonia*	41.6
Bow River	8,264	Nitrate ion	90.8
Ottawa River	3,066	Ammonia*	76.6
North Saskatchewan River	2,953	Nitrate ion	61.3
Red River	2,766	Ammonia*	72.7
Hamilton Harbour	1,516	Ammonia*	70.6
South Saskatchewan River	1,275	Nitrate ion	62.4
St Lawrence River	1,086	Nitrate ion	43.6

*Total includes both ammonia (NH_3) and ammonium ion (NH_4+) in solution.

Source: Statistics Canada (2003b: 18).

From: Dearden and Mitchell (2012)

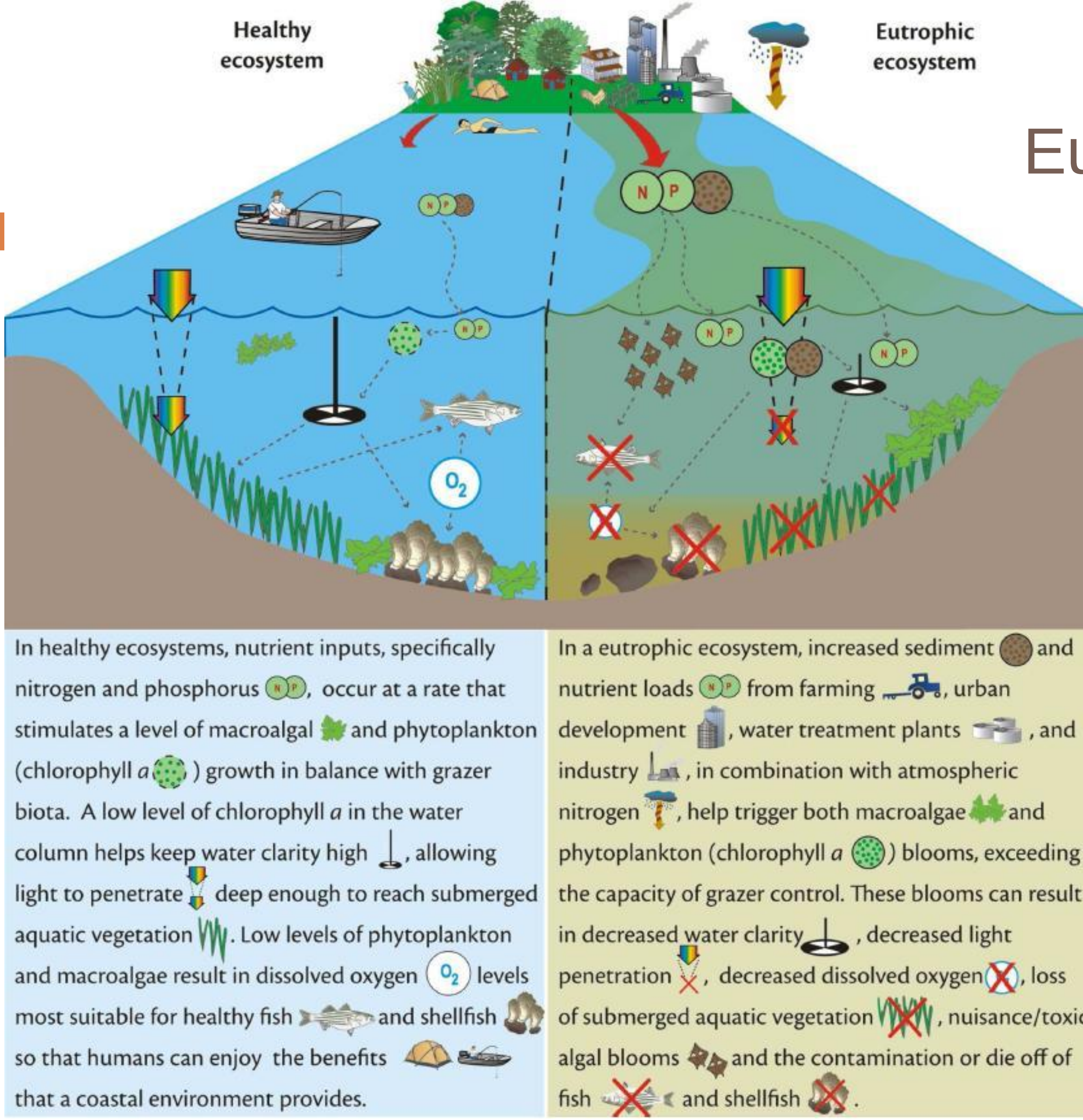
Non-point Sources

- Diffuse pollution has been a policy issue in the Great Lakes Basin since the 1960s – media declared that "Lake Erie was dying"….concerns arose about:
  - sedimentation from soil erosion;
  - eutrophication from nutrient loading; and
  - toxic chemicals

Courtesy of Jim Schafer … Orange-brown water from the Cuyahoga River spills out of Cleveland harbor and into Lake Erie, a regular occurrence during the late 1960s when this photo was taken by members of the city's Bureau of Industrial Wastes.

http://www.cleveland.com/science/index.ssf/2009/06/cuyahoga_river_fire_40_years_a.html

Eutrophication



From Environment Canada (2011) but adapted by EC from Bricker et al. (2007)

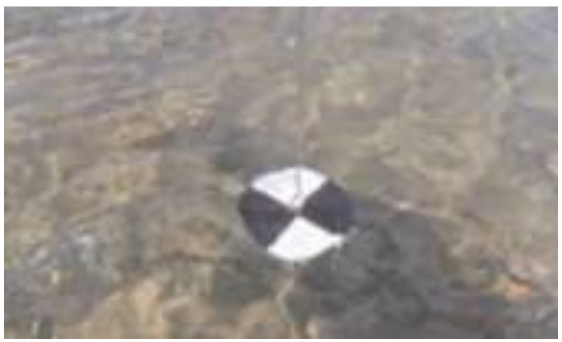
Government of Canada Gouvernement du Canada

Environment Canada

Water Quality Issues

- Nutrients (phosphorus and nitrogen)

  → Eutrophication … 3 of 5 levels shown below…

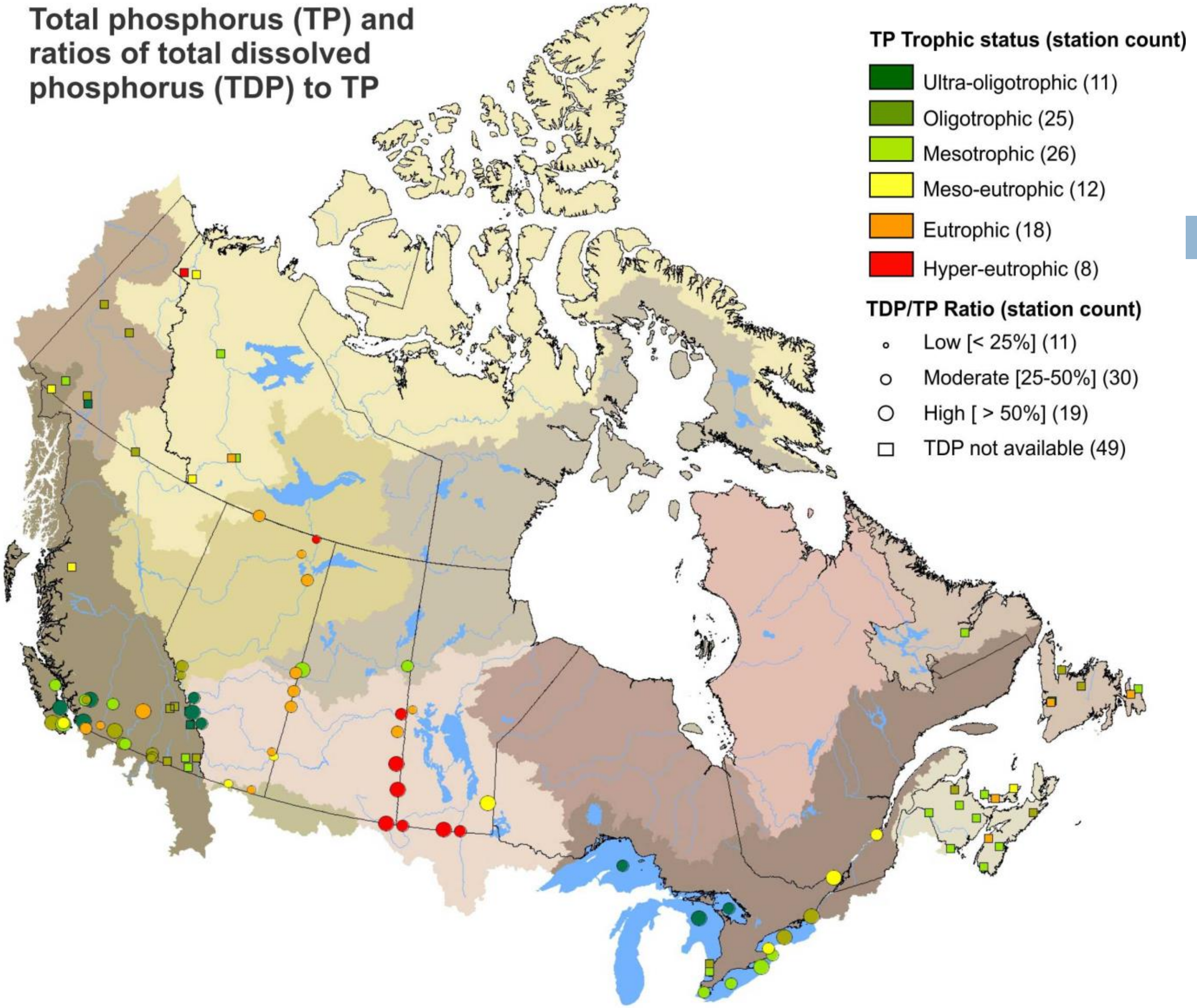


“Ultra-oligotrophic”
total phosphorus <0.004 mg/L
low nutrients, low plant growth
high water clarity

“Mesotrophic”
total phosphorus 0.01 – 0.02 mg/L
moderate nutrients/plant growth
reduced water clarity

“Eutrophic”
total phosphorus 0.035-0.100 mg/L
high nutrients/plant growth
very limited water clarity

Environment Canada “*Phosphorus in Canada’s Aquatic Ecosystems*” www.ec.gc.ca/



Concentration levels of total phosphorus (TP) and ratios of total dissolved phosphorus (TDP) to TP in rivers and the Great Lakes, Canada, 2004 to 2006. From Environment Canada. *** Note that some areas have naturally low or high levels of phosphorus.***

The algae blooms

Algal blooms, Sept 2009 on Lake Erie

http://www.noaanews.noaa.gov/stories2013/images/

<u>Above image from 2011</u> – the worst bloom in decades

- Swathes of blue-green algae (form due to high phosphorus inputs) … big news in 2013 on Lake Erie
- Potential tourism and shipping impacts?

Total Phosphorus Loadings (1976 → 1991) Lake Erie

- initial plans of International Joint Commission (IJC) for Great Lakes in 1970s to reduce municipal loading of nutrients

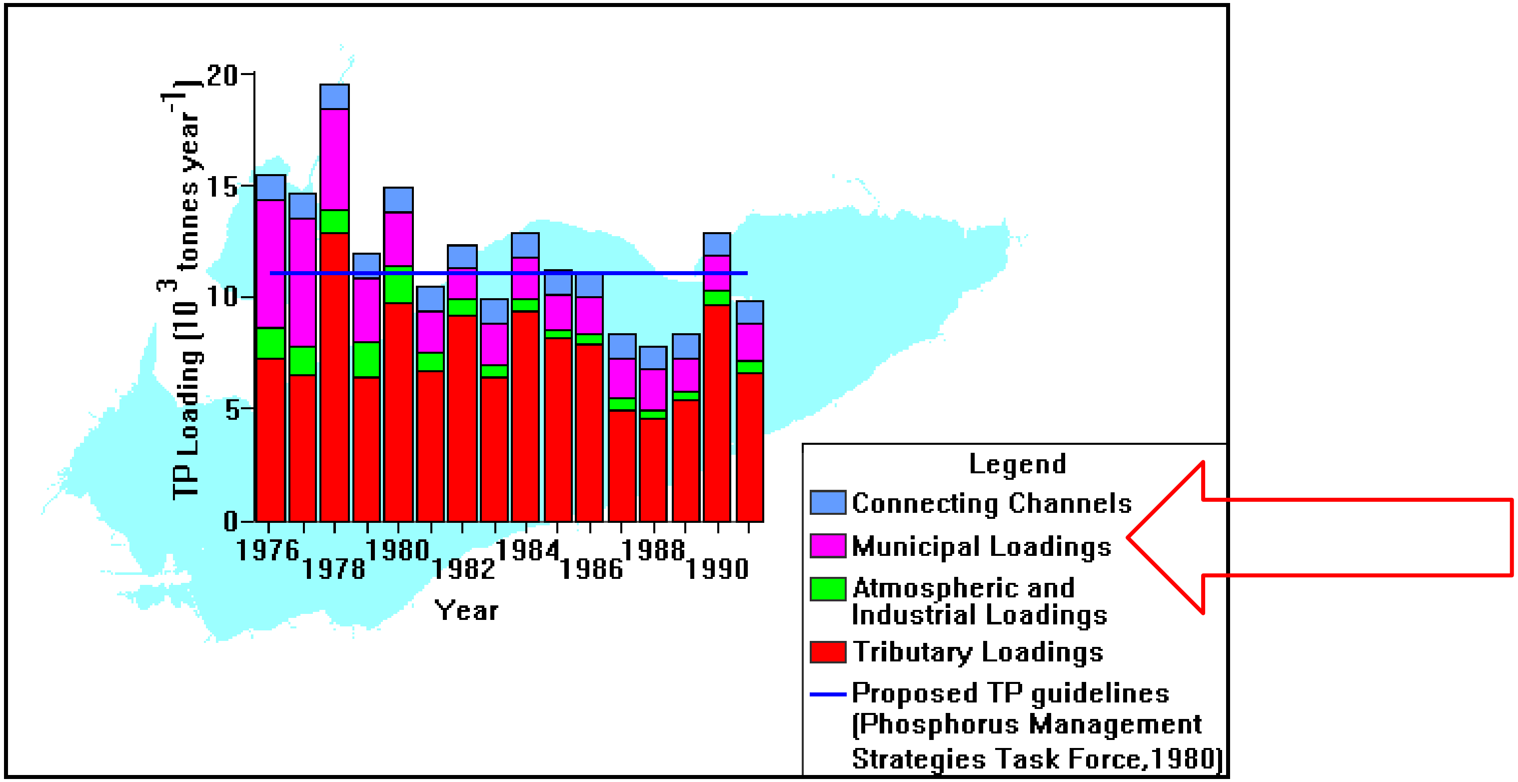


Figure 42 Lake Erie total phosphorus loads (Ref. 22). (Reproduced by permission)

PLUARG : International Reference Group on Great Lakes Pollution from Land Use Activities

- The IJC was asked to study pollution in the Great Lakes from agricultural, forestry and other land uses that are potential non-point sources;
- **the study was completed by PLUARG:**
  - Study focused on (1) eutrophication from elevated nutrients, and (2) toxic contaminants
  - They examined agriculture, urbanization, forestry, transportation, waste disposal, and natural processes;

PLUARG : International Reference Group on Great Lakes Pollution from Land Use Activities

- **PLUARG Study conclusions:**
  - the combined non-point inputs ranged from 32% to 90% of total phosphorus loads;
  - 1976 loads exceeded recommended targets in all the Great Lakes
  - this was the first credible science to document the important contribution of non-point sources to phosphorus loading, and was difficult (for governments) to ignore
  - other findings……

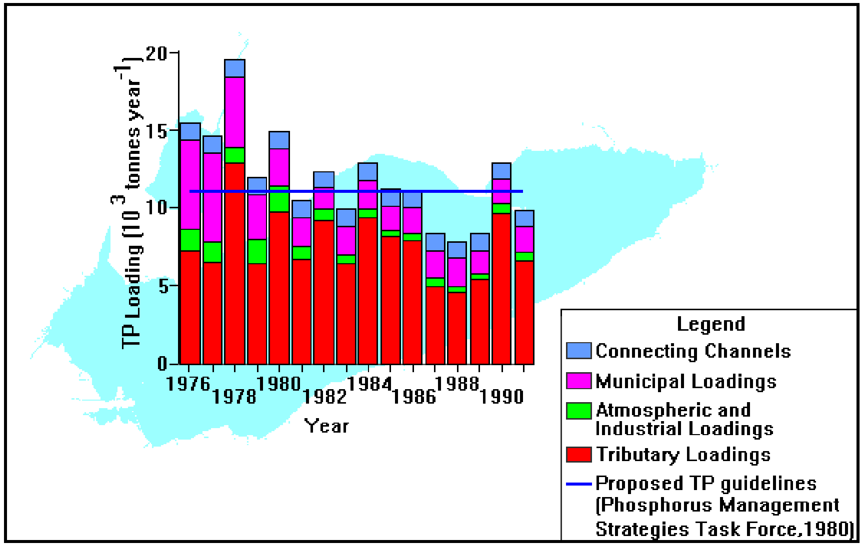


Figure 42 Lake Erie total phosphorus loads (Ref. 22). (Reproduced by permission)

PLUARG : International Reference Group on Great Lakes Pollution from Land Use Activities

- **PLUARG Study conclusions (Other major findings):**
  - Toxic substances such as PCBs were entering from diffuse sources, especially atmospheric deposition
  - Residues of organochlorine pesticides such as DDT were still entering via land drainage
  - Intensive agricultural operations were the main contributor of phosphorus
    - Erosion from crop production and urbanization were main sources of sediment
    - Urban runoff and atmospheric deposition were the major diffuse contributors of toxic substance

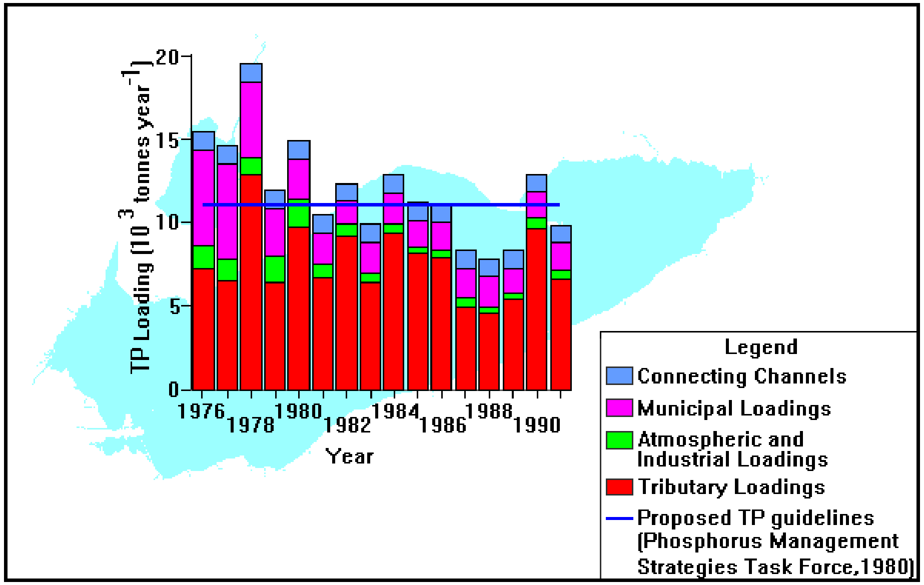
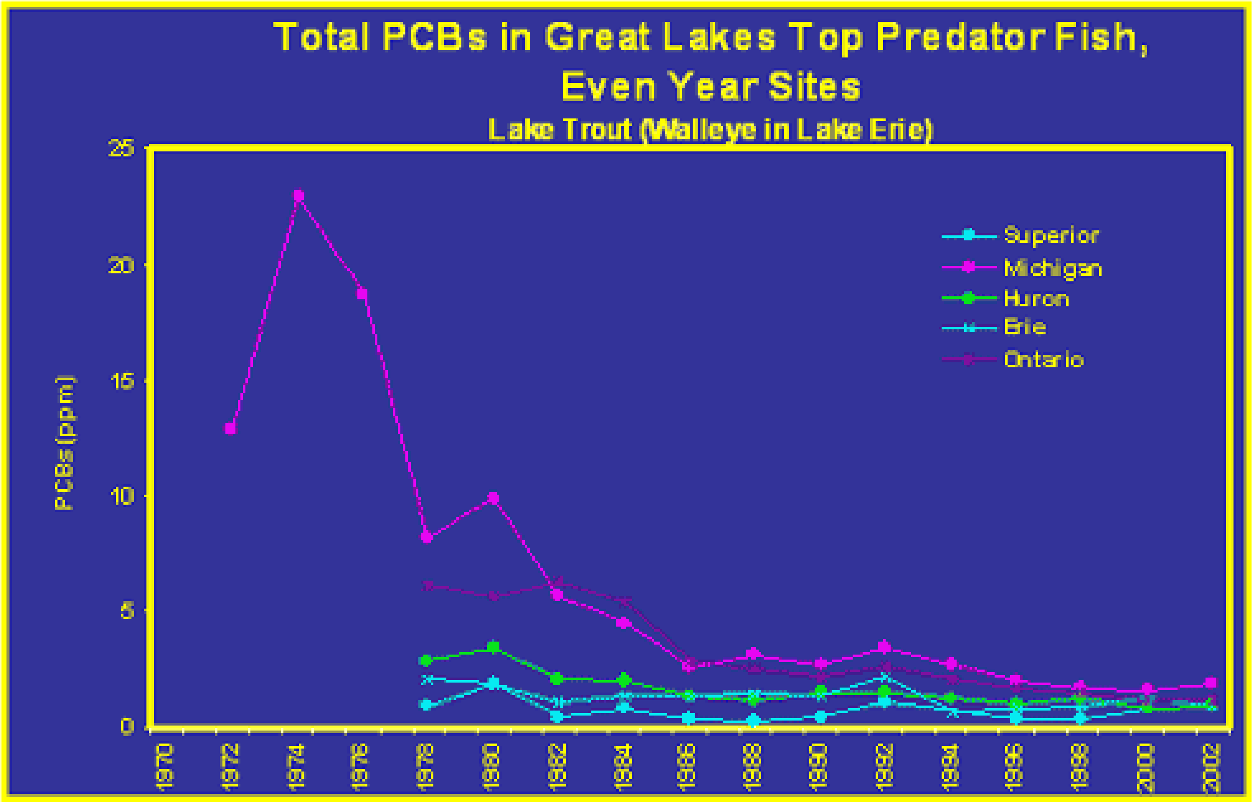


Figure 42 Lake Erie total phosphorus loads (Ref. 22). (Reproduced by permission)

Great Lakes Monitoring



The above graph illustrates that PCB concentrations in Great Lakes top predator fish are declining. However, it is important to note that the concentrations of this contaminant remain above the wildlife protection value of 0.16 ppm and the GLWQA criteria of 0.1 ppm. PCB fish advisories remain in place for all 5 of the Great Lakes.

Source: US Environmental Protection Agency
http://www.epa.gov/glindicators/fishtoxics/topfishb.html

Water Security

A daily necessity…

- A key concern in water management is to provide enough water of adequate quality for human use
- As of 2010, over 1 in 6 people on Earth lacked access to safe water supplies, and 2 of 5 had no access to adequate sanitation
- Per capita water use varies widely, from under 20 litres/day to over 500 l/day in countries like Canada
- minimums for human health is 3L/day in temperate climates; 5L/day in tropical areas;

Per Capita Water Use (Canada vs …)

Comparison of per capita residential water consumption (from Sharratt *et al.*, 1994) and costs (from Environment Canada, 1992).

jurisdiction	**water consumption (L/c/d)**	**water prices (1989 CAD/m^3)**
USA	426	0.42
Ontario	***300***	***0.36***
Sweden	200	0.78
Germany	150	1.33
France	150	0.86
Australia	n/a	1.47

Notes: L/c/d = Litres per capita per day; 1000 L = 1 m^3.

Canadian water use …

- Most Canadians have access to treated, municipal water; others depend on private wells
- Canadians in rural areas use groundwater
- The relative abundance of water in Canada, the high levels of water use, and the myth of superabundance make most Canadians complacent about the adequacy and safety of their water supplies
- This changed in 2000, when the small town of Walkerton, Ontario experienced contamination of its water supply system by Escherichia coli .. in which 7 people died and >2,300 people became ill

The Walkerton Inquiry

- **A public inquiry established that:**
  - A well had been contaminated by manure, despite proper manure-spreading methods;
  - Chlorination equipment was being repaired and would have prevented contamination if it were operating;
  - Provincial government approval and monitoring programs were inadequate;
  - Well operators were not trained and there was a history of improper operating practices;
  - The water manager withheld adverse water quality information, delaying a boil-water advisory;
  - Government water-testing labs had been shut down due to budget cuts, and private labs weren't required to submit results;

Walkerton: Lessons and Recommendations

- **Inquiry recommended a multi-barrier approach to drinking water safety with**:
  - A comprehensive watershed management approach
  - A watershed-based source-protection plan framework
  - Planning at the local watershed level by those most affected, to ensure goodwill and acceptance
- Since this report, this approach has been adopted by other federal and provincial governments, Walkerton residents have been compensated financially, the Walkerton Clean Water Centre opened, and training has been provided across Ontario

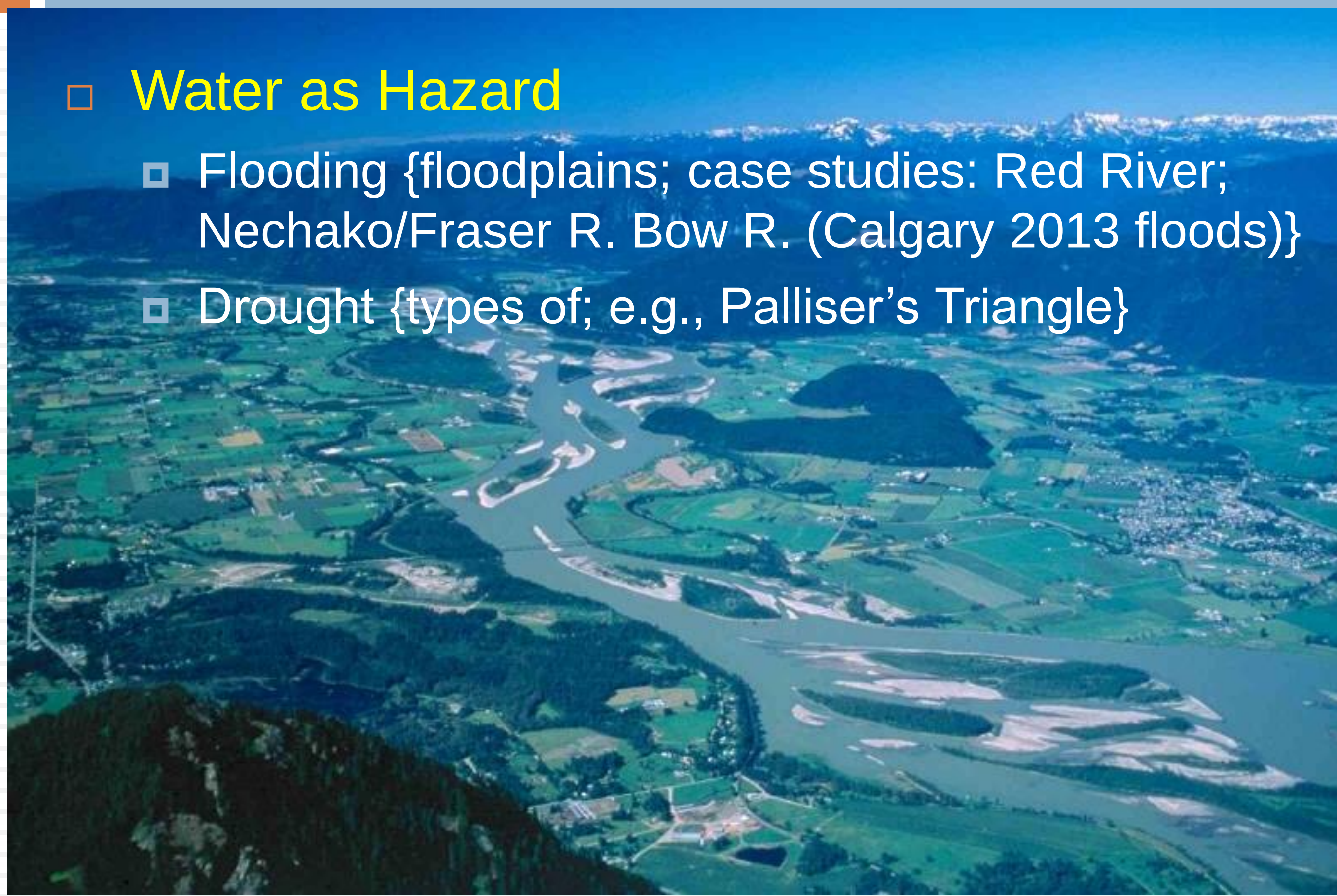
References

- Dearden, P and Mitchell, B. 2012. *Environmental Change and Challenge*, Fourth Edition, Don Mills, Ontario: Oxford University Press {Chapter 11: ‘Water’}

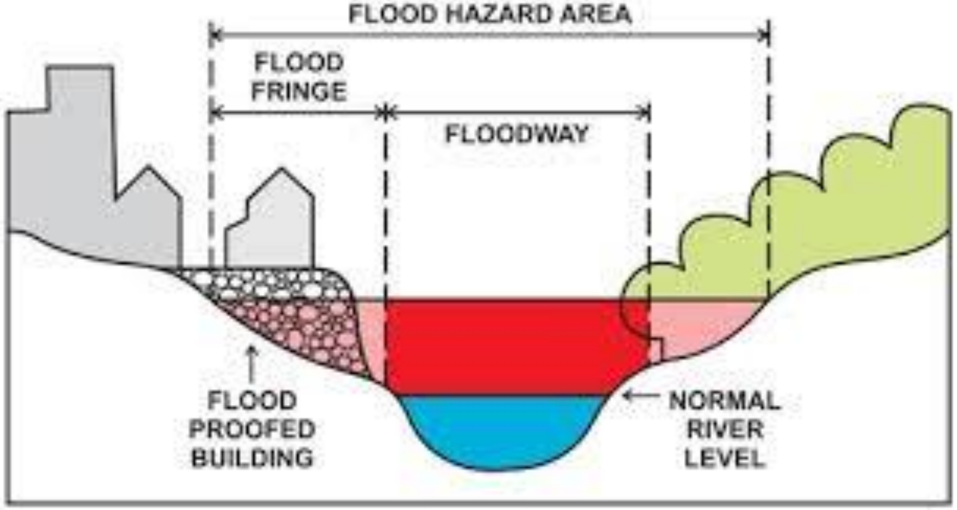
- Environment Canada. “About Fresh Water Quality Monitoring & Surveillance” http://ec.gc.ca/eaudouce-freshwater/default.asp?lang=En&n=50947E1B-1

Part 3: Water as Hazard

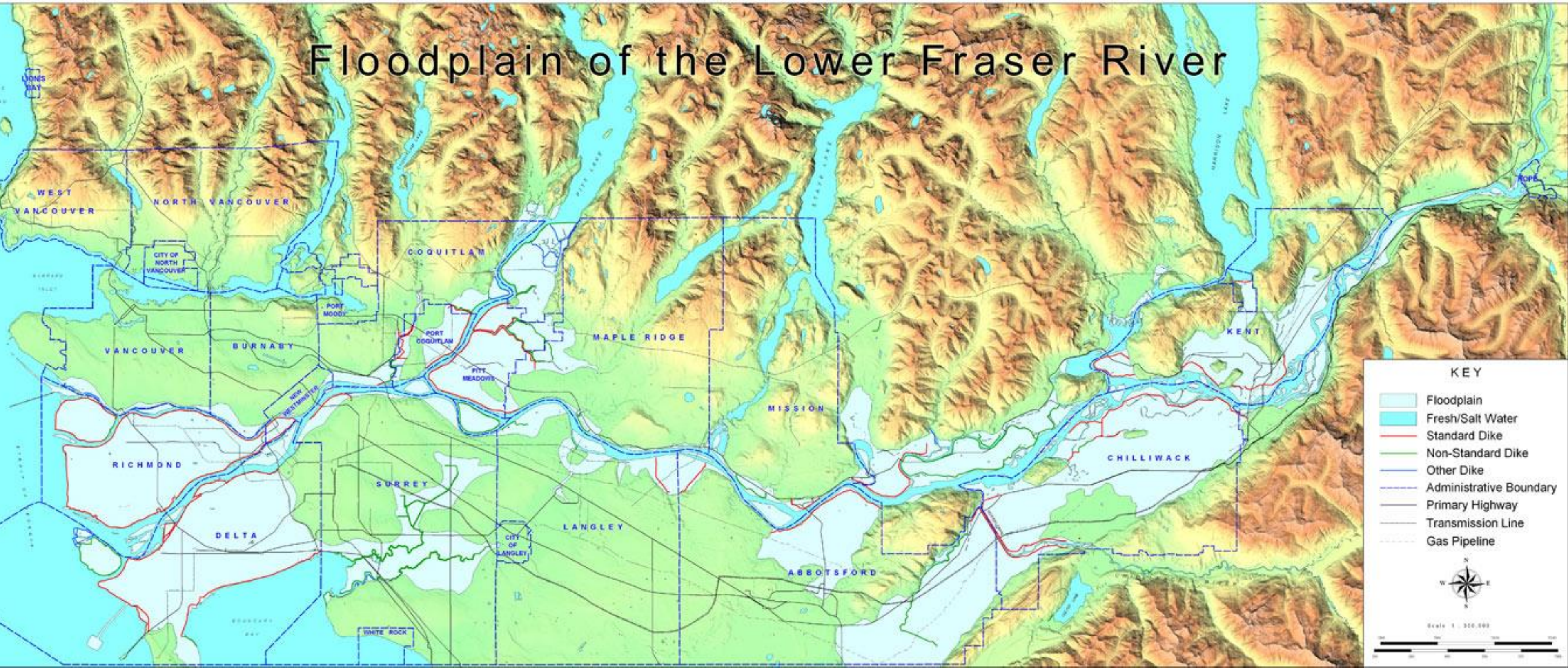
- Water as Hazard
  - Flooding {floodplains; case studies: Red River; Nechako/Fraser R. Bow R. (Calgary 2013 floods)}
  - Drought {types of; e.g., Palliser's Triangle}



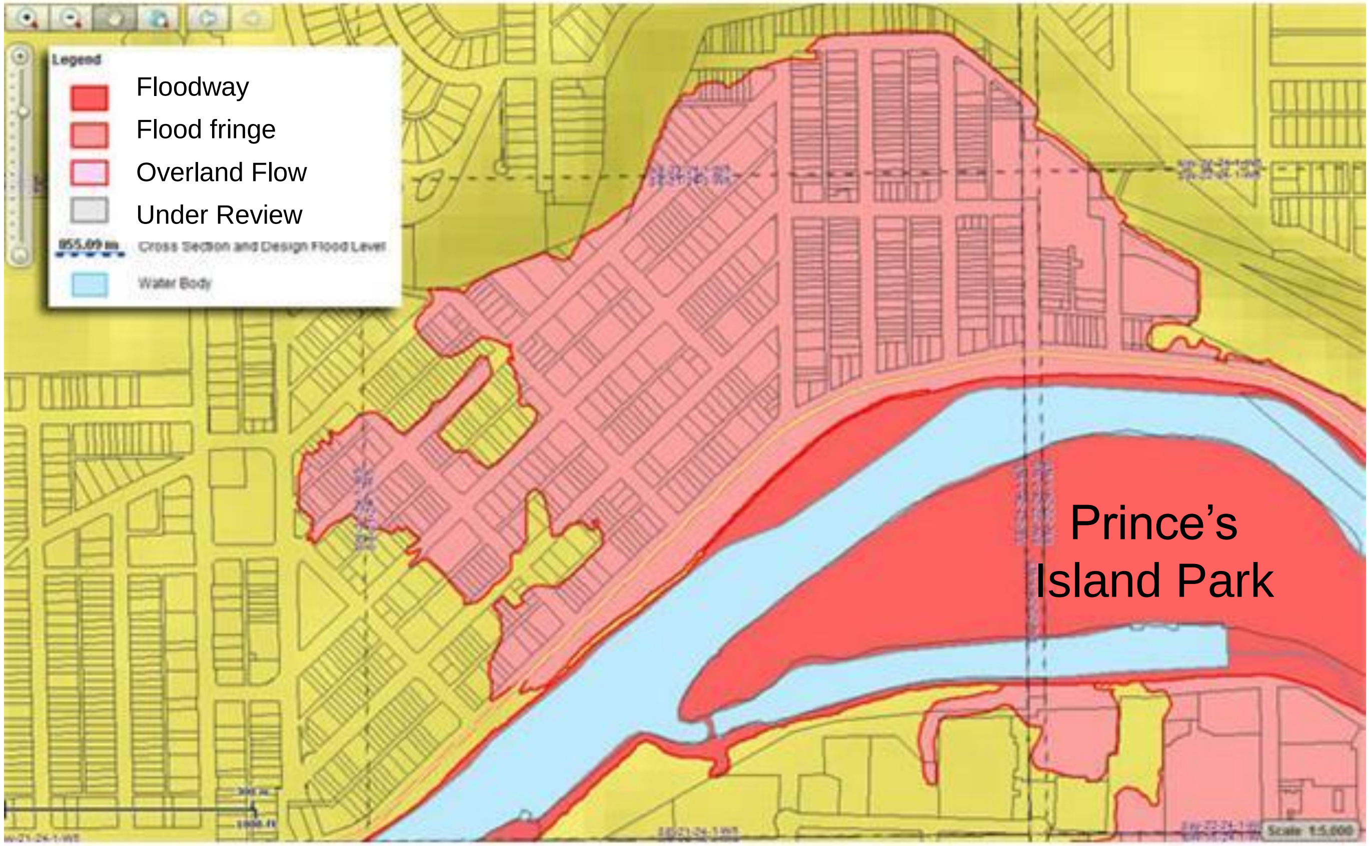
- Floodplain Distinctions
  - A **floodplain** is low-lying land along a river or lake that floods from time to time under normal conditions;
- **Floodway**: area necessary to transmit a selected flood; damage to structures is likely; thus development severely restricted
- **Floodway Fringe**: may be suitable for certain developments



Floodplain, Lower Fraser Valley



Floodplain map (example, Calgary)



Note: infringement of built up areas on flood plain areas;

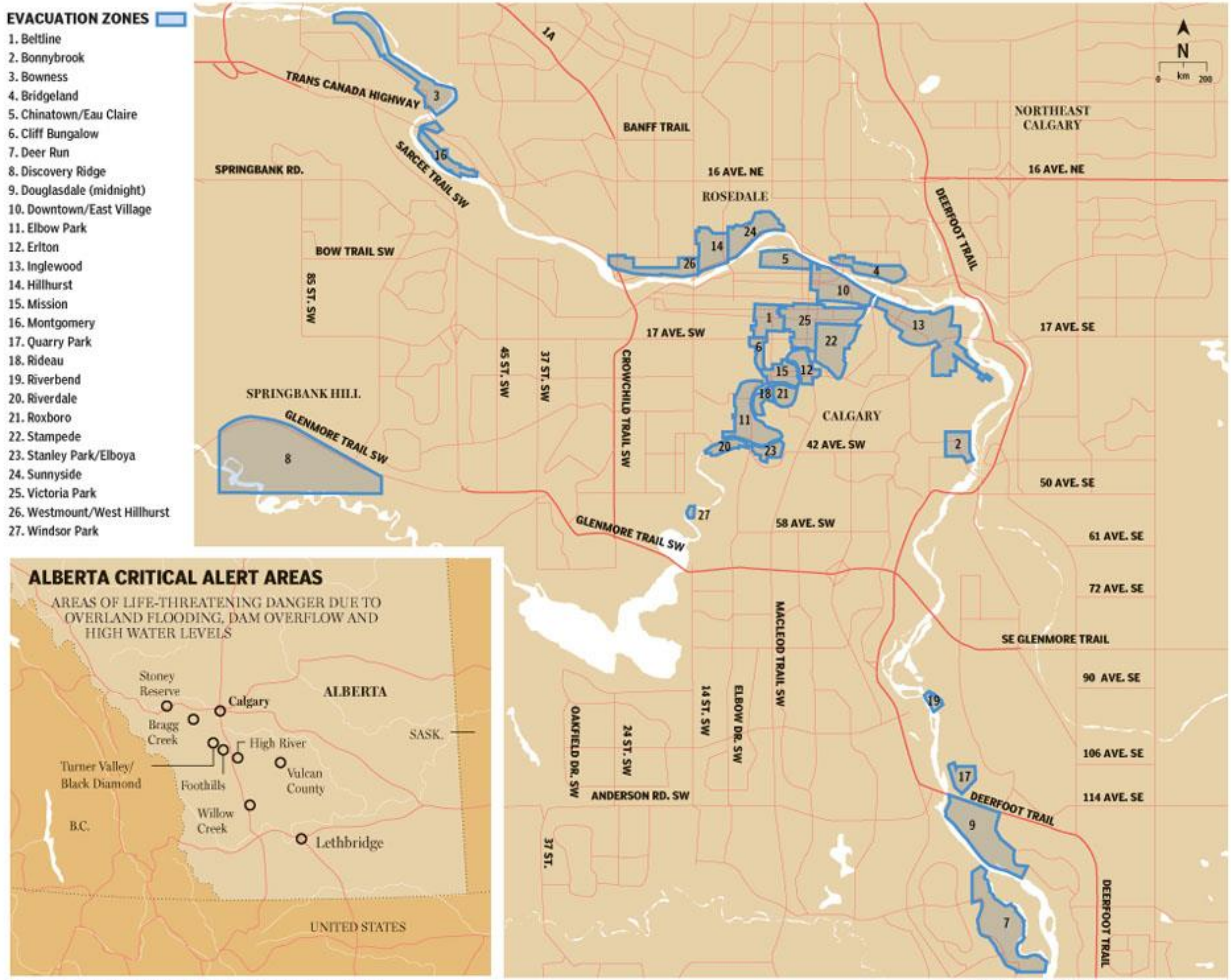
Preamble: water as hazard

- **Flooding**
- As population concentrations on floodplains increase, the potential of flood damage goes up
- Major flood events have frequently caused enormous damage across Canada:
- Notable Canadian examples:
  - Fraser River (1948)
  - Manitoba floods (1997 $300 million; 2011 $550 million)
  - Toronto – Hurricane Hazel (1952, 80 deaths)
  - Saguenay River Valley, QC (1996, 10 deaths; $800 million)
  - Calgary / Southern Alberta (2013, 4 deaths; >100,000 displaced residents, $1.7 billion)

Southern Alberta Floods

- Lasted June 19 to July 12, 2013
- Caused by major precipitation events in Rocky Mountains to west
- 4 deaths;
- >100,000 displaced residents
- Estimated $1.7 billion in damages
- Affected communities, notably Calgary, High River … some residents out of their homes for months; other homes never to be re-occupied
- Re-assessment of floodway risk

FLOODING IN ALBERTA TRIGGERS EVACUATIONS IN CALGARY



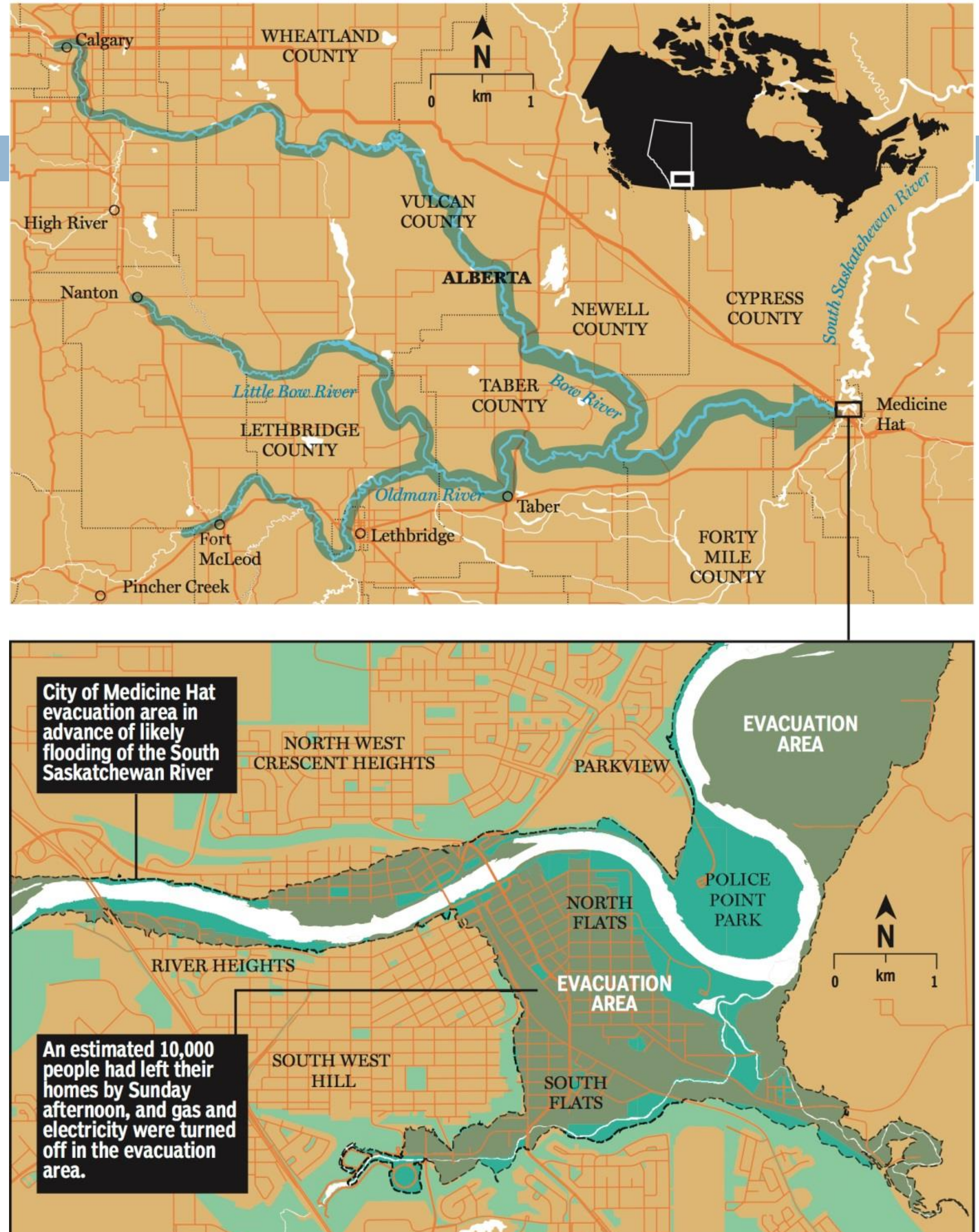
SOURCE: CALGARYCITYNEWS.COM, EMERGENCYALERT.ALBERTA.CA

ANDREW BARR, MIKE FAILLE / NATIONAL POST

Calgary floods June-July 2013

FLOOD FEARS SHIFT TO MEDICINE HAT

According to the City of Medicine Hat website, the South Saskatchewan River is expected to peak early Monday with a flow rate between 5,100 to 6,000 cubic metres per second.



Water as Hazard

Flooding

- There are various ways of reducing flood damage:
  - ***Structural*** approaches modify the behaviour of the natural system by delaying or redirecting flood waters, e.g., dams, storage reservoirs, dykes, or levees
  - ***Non-structural*** approaches focus on modifying the behaviour of people, e.g., land-use zoning, education, and insurance programs
- The best strategies employ both approaches

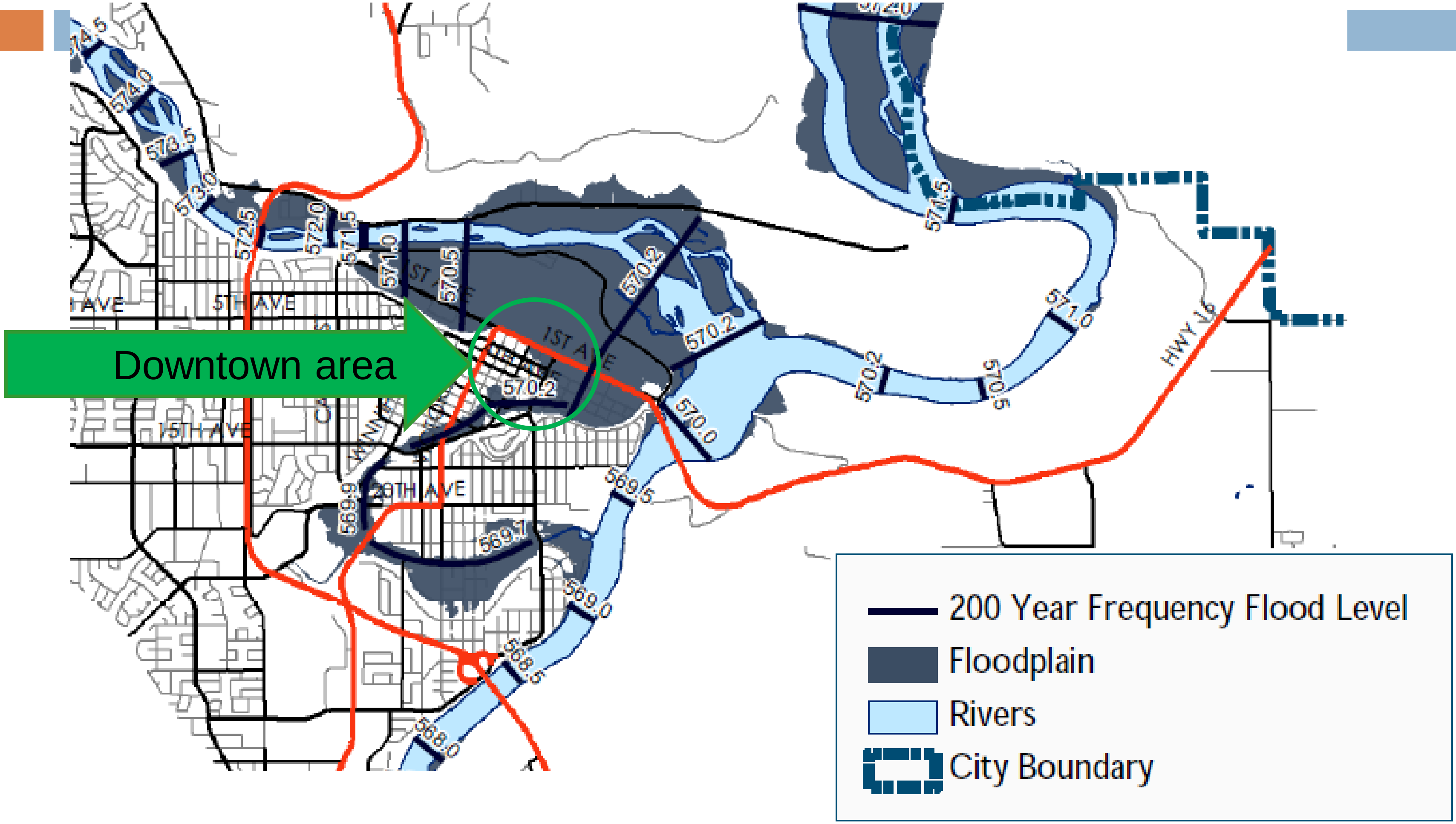
Non-structural approaches

Zoning

Relocation of flood prone structures

Photo:
Old Fort William Historic Park along Kaministiquia River (shown in flood conditions)
*** The Kam is a regulated river.*

City of Prince George Floodplain



Source: City of Prince George Flood Plain Bylaw:
http://princegeorge.ca/citybusiness/currentplanning/floodplainbylaw/Pages/Default.aspx

Nechako River Floodplain at Prince George, August 2005

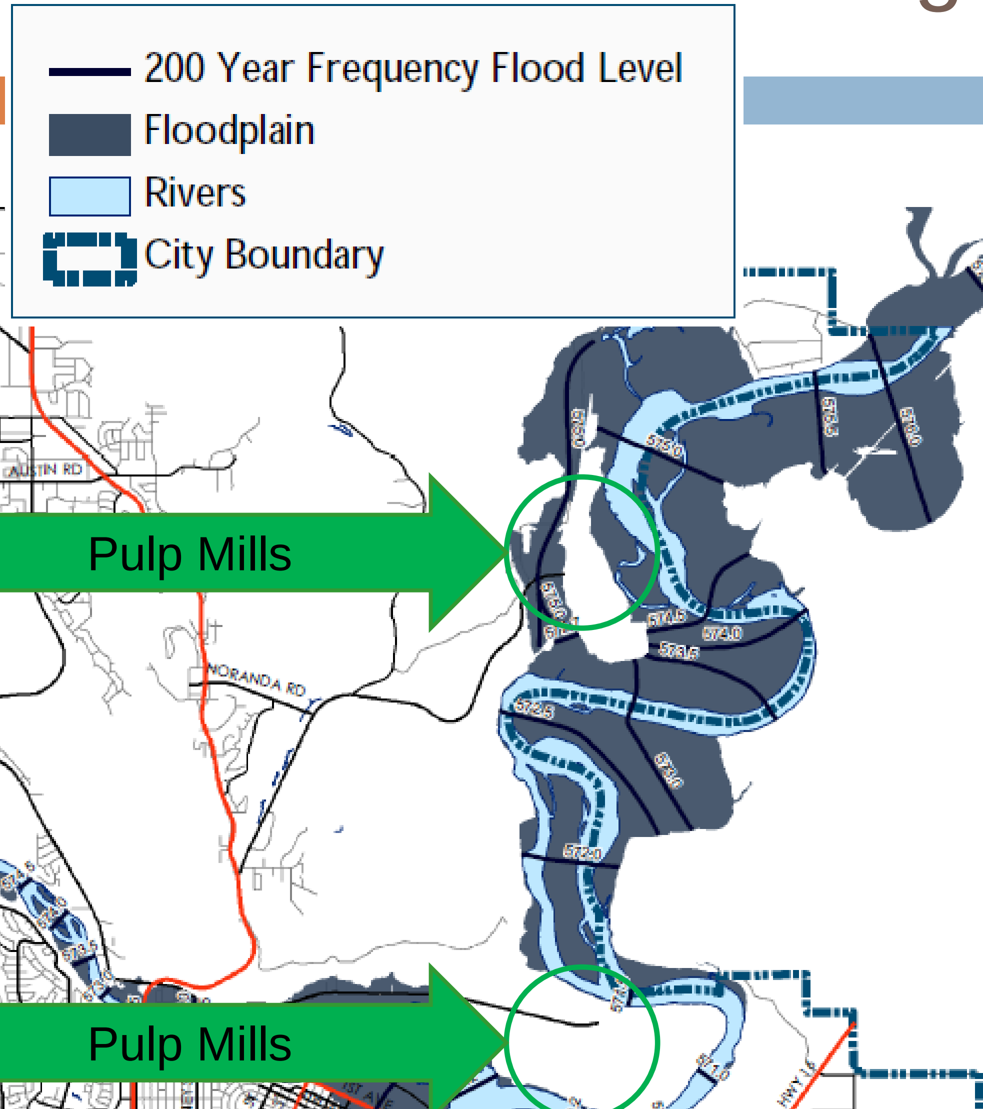
Sawmills (in view) and downtown (not shown) vulnerable (at one time) to regular flooding – **ironic** to have noted this in 2006 given events of June and Dec 2007

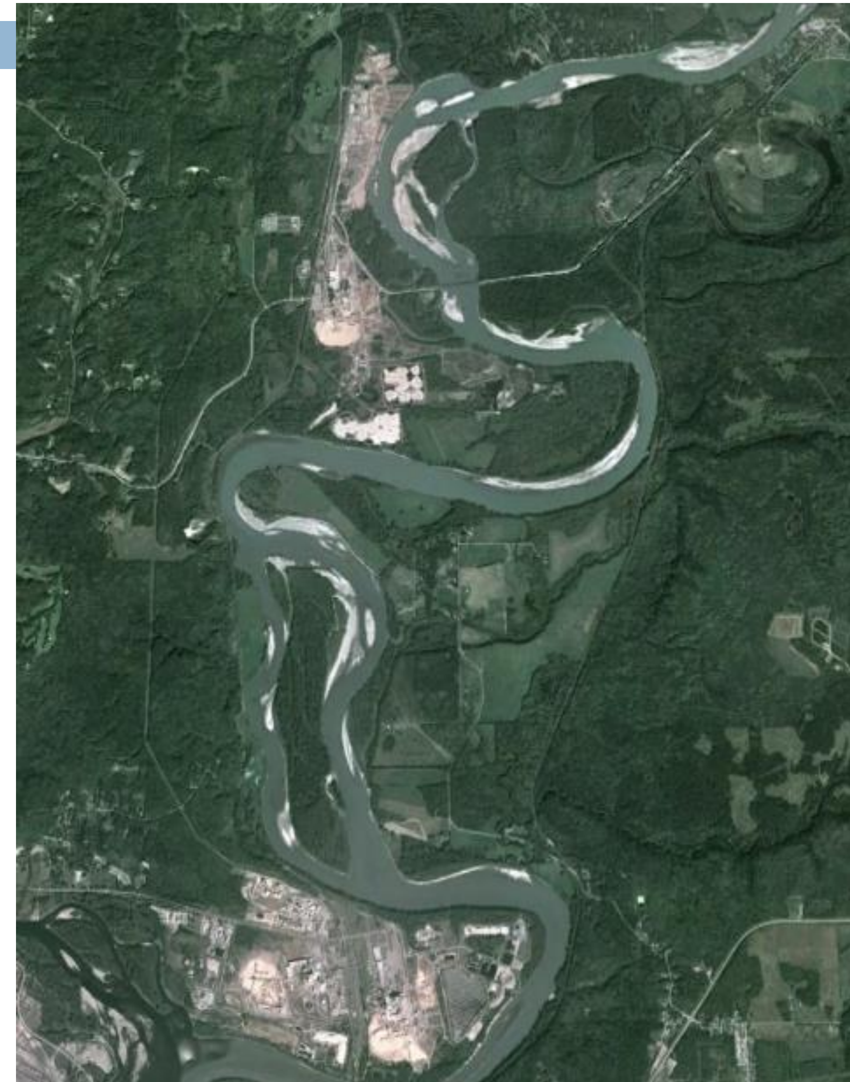
Flooding (due to ice jam) on Nechako R at Prince George, December 2007

Nechako R. in flood (June 2007) at Vanderhoof, BC (pop 4,500), ~100 km west of Prince George

Photo Credit: Nechako River, D.L. Randall (June 2007).

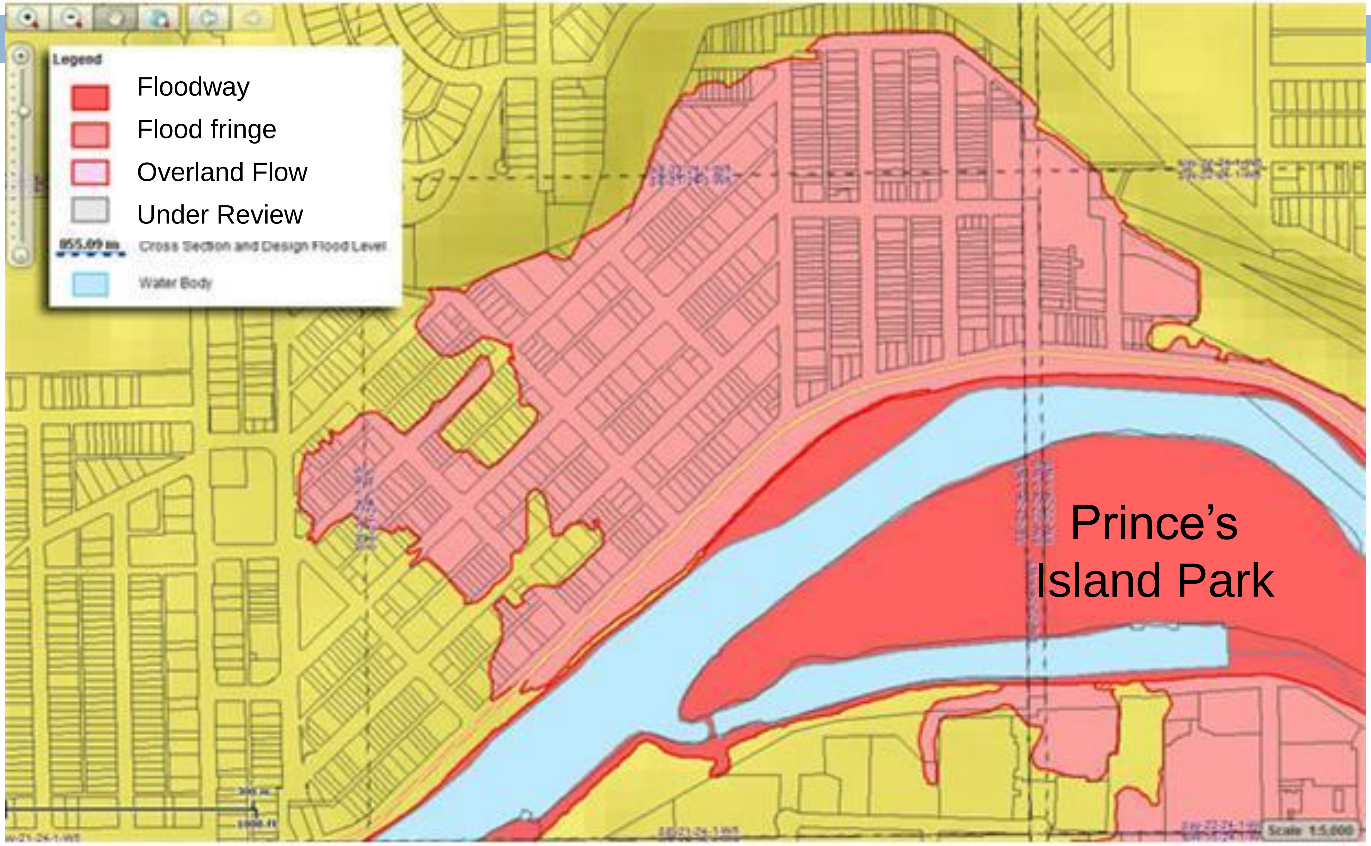
City of Prince George Floodplain





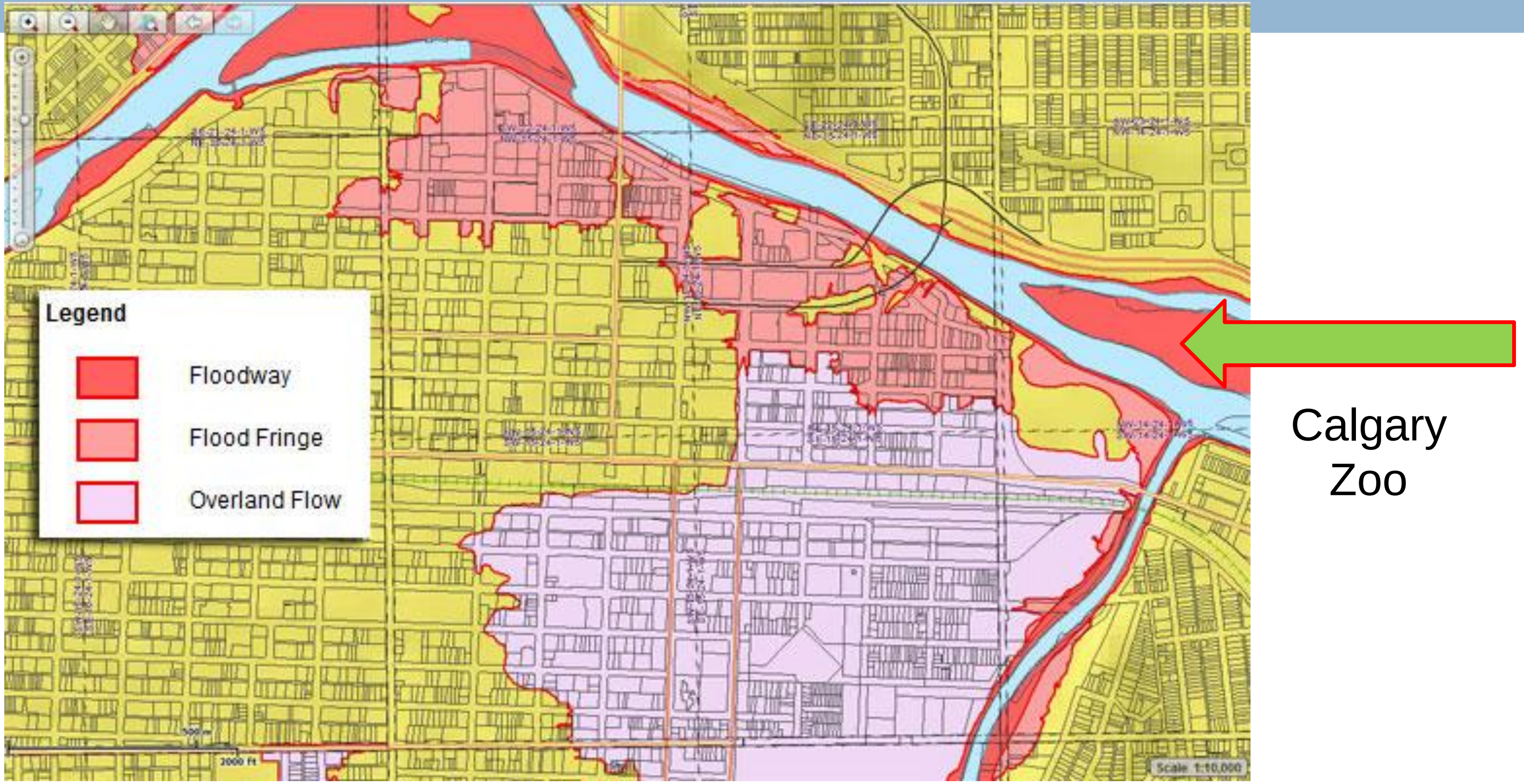
Source: City of Prince George Flood Plain Bylaw:
http://princegeorge.ca/citybusiness/currentplanning/floodplainbylaw/Pages/Default.aspx

Calgary flood 2013: revised flood fringe zones (Sunnyside)



A large swath of Sunnyside is now in a designated flood fringe zone, meaning homeowners must floodproof if they want to get government help repairing after future floods. The provincial government says it will help people rebuild this time, but that homeowners who live in floodways or "flood fringes" will have to take certain precautions and can't expect government help next flood.

Calgary flood 2013



Parts of Downtown Calgary and Mission are in the flood fringes and susceptible to overland flooding. The provincial government says it will help people rebuild this time, but that homeowners who live in floodways or "flood fringes" will have to take certain precautions and can't expect government help next flood.

Structural approaches

Dams
Reservoirs
Dykes
Levees
Channel straightening

Case Study: Red River Flood, 1997

Flooding: Red River Flood, 1997

- The Red River originates in the northern US (N. Dakota, Minnesota) and flows northward, draining into Lake Winnipeg
- In spring 1997, the Red River experienced a catastrophic flood due to …
  - high precipitation the previous fall that saturated the soil
  - near-record high winter precipitation
  - a long and unusually cold winter (→ large snowpack, little winter melt)
  - a major blizzard in early April
- The widespread flooding of the Red River valley was typical for that river system, which is a broad, flat area that promotes slow flood rise and fall

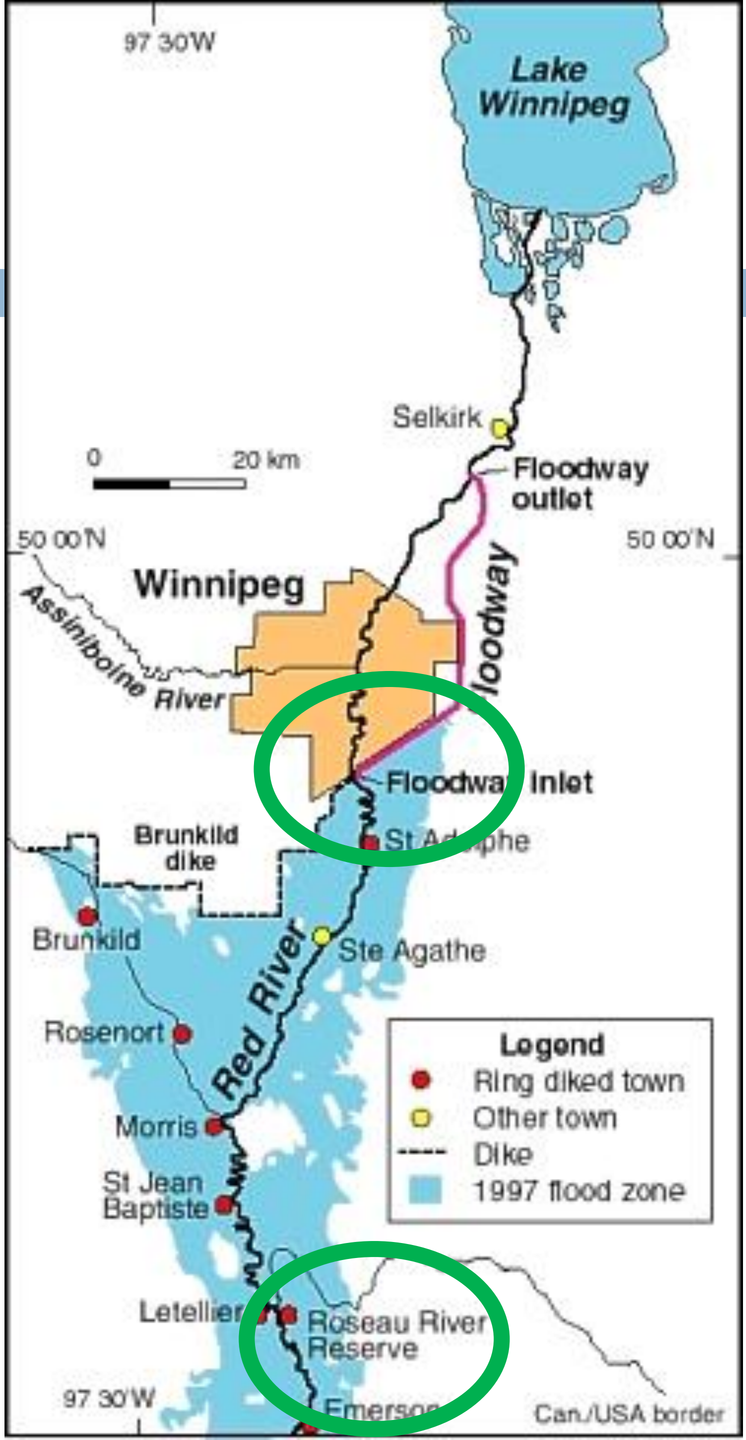
Extensive flooding near Roseau River Reserve

Flooding: Red River Flood, 1997

- A previous major flood (in 1950) precipitated the construction of a number of structural measures to mitigate the flooding hazard including:
  - The **Red River Floodway**, an excavated channel that diverts water around Winnipeg's eastern boundary back into the Red River downstream
  - The Portage diversion, an excavated channel west of Winnipeg that diverts water into Lake Manitoba
  - The Shellmouth Dam and Reservoir
  - Earth dykes along the Red, Assiniboine and Seine rivers
  - Ring dykes south of Winnipeg
  - Elevated roads and railway beds

Red River Floodway

- Significantly abated the 1996 and 1997 flood events



Winnipeg spillway – inlet; in operation during 1997 flood

Flooding Near Emerson, Manitoba in the Spring of 1997

The photo taken looking northward shows the Red River Plain near the International Border during the 1997 flood. The normal channel of the Red River, which at times carried more than 120,000 cfs, is picked out by woodland along its banks (1). A ring dike (2) protected Emerson (3), as well some land (4) south of the US border (5), from flooding. The CN railway line (6) crosses the Red River to the west, and the CP line (7) ,which runs northeast from Emerson, appears to be flooded north of the ring dike (8). Flood waters, no respecter of political boundaries, cover vast areas north (9) and south (10) of the border.

Source of image and text: *http://mbair.brandonu.ca/book/chapter/16/58*

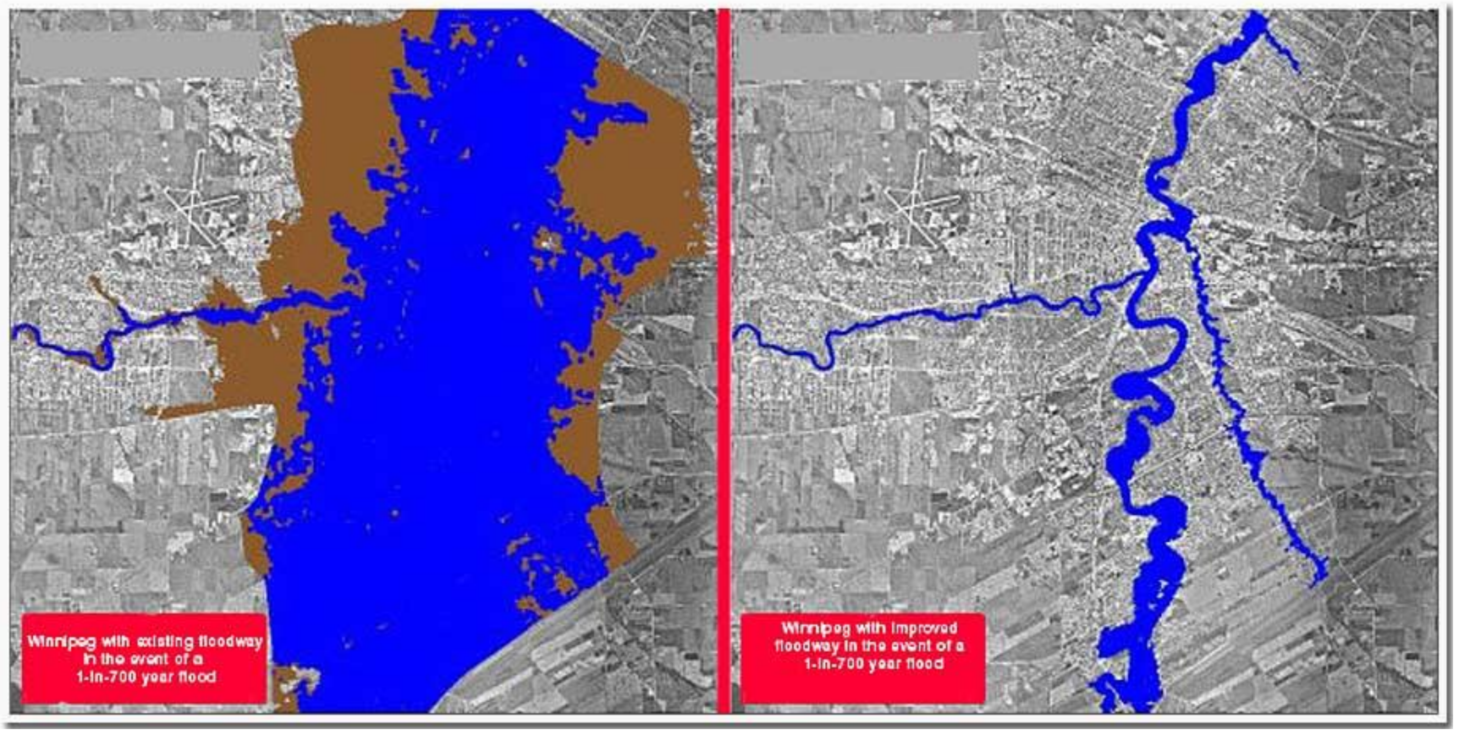
Flooding: Red River Flood, 1997

- Structural measures (together with community efforts) greatly limited damage during the 1997 flood, however there were negative outcomes:
  - Several small upstream communities were flooded due to operation of the floodway gates
  - Peak flow had been underestimated by ~1.6 metres, leading to non-dyked communities being flooded
  - Some rural municipalities delayed action due to provincial rules that don't allow running a deficit
  - Some aboriginal communities weren't protected due to confusion regarding agency jurisdiction

Flooding: Red River Flood, 1997

- Following the 1997 flood, the IJC (International Joint Commission) concluded that:
  - future such major floods could occur (another major flood occurred in 2009)
  - the Red River Valley would remain at risk unless a comprehensive, integrated, bi-national strategy was in place
  - a mix of structural and non-structural approaches is needed
  - specific communities needed flood damage initiatives
  - ecosystem factors needed more consideration (e.g., hazardous materials and banned substances should be removed from potential flood areas)

- Since 1997 the Canadian and Manitoba governments have spent over $130 million on structural measures (mostly in rural communities), have enlarged the Red River Floodway to be able to handle a once-in-700-year flood, and have made improvements to bridges, dykes, utilities, and drainage services;



Potential impact of 700 year flood on Winnipeg without the *improved* floodway (left). *Source:* Natural Resources Canada

Water as Hazard: **Droughts**

- Droughts …the opposite problem to that of floods…
- **Droughts** are a function of lack of precipitation, temperature, evaporation, evapotranspiration, capacity of soil to retain moisture, and resilience of flora and fauna
- Droughts can lead to a ‘depletion cycle’ where reduced rainfall leads to low soil moisture, triggering irrigation demands, which depletes groundwater supplies

Photo credit: N. Dakota State University
http://www.ag.ndsu.edu/drought/

Droughts

- Identifying ‘drought-prone’ areas is challenging because a ‘drought’ is difficult to define
  - Droughts defined by *cause*:
    - meteorological droughts caused by deficiency of precipitation, and hydrological droughts caused by reduced stream flows and a lowered water table and/or lake levels;
    - the first can trigger the second
  - Droughts defined by *effects*
    - agricultural droughts where a lack of moisture reduces crop yields, and urban droughts where low stream flows or water tables lead to insufficient water to support community demands

- Droughts are often associated with the Prairie provinces, especially in that area of southern Alberta, Saskatchewan, and extreme southwest Manitoba known as **Palliser's Triangle**
  - drought conditions affected over ¾ of the Prairie provinces in 2002 (Figure 11-6, Dearden and Mitchell, 2012), and are likely to become more common in our post-glacial conditions

WORST KNOWN

DROUGHT IN CANADA

Wheat Areas Ravaged

INTENSE HEAT EXPERIENCED

(Australian Cable Service.)

VANCOUVER, June 27.

The hottest June days for 60 years killed 50 persons in the eastern part of the United States yesterday and to-day.

Temperatures in many cities exceeded 100 deg.

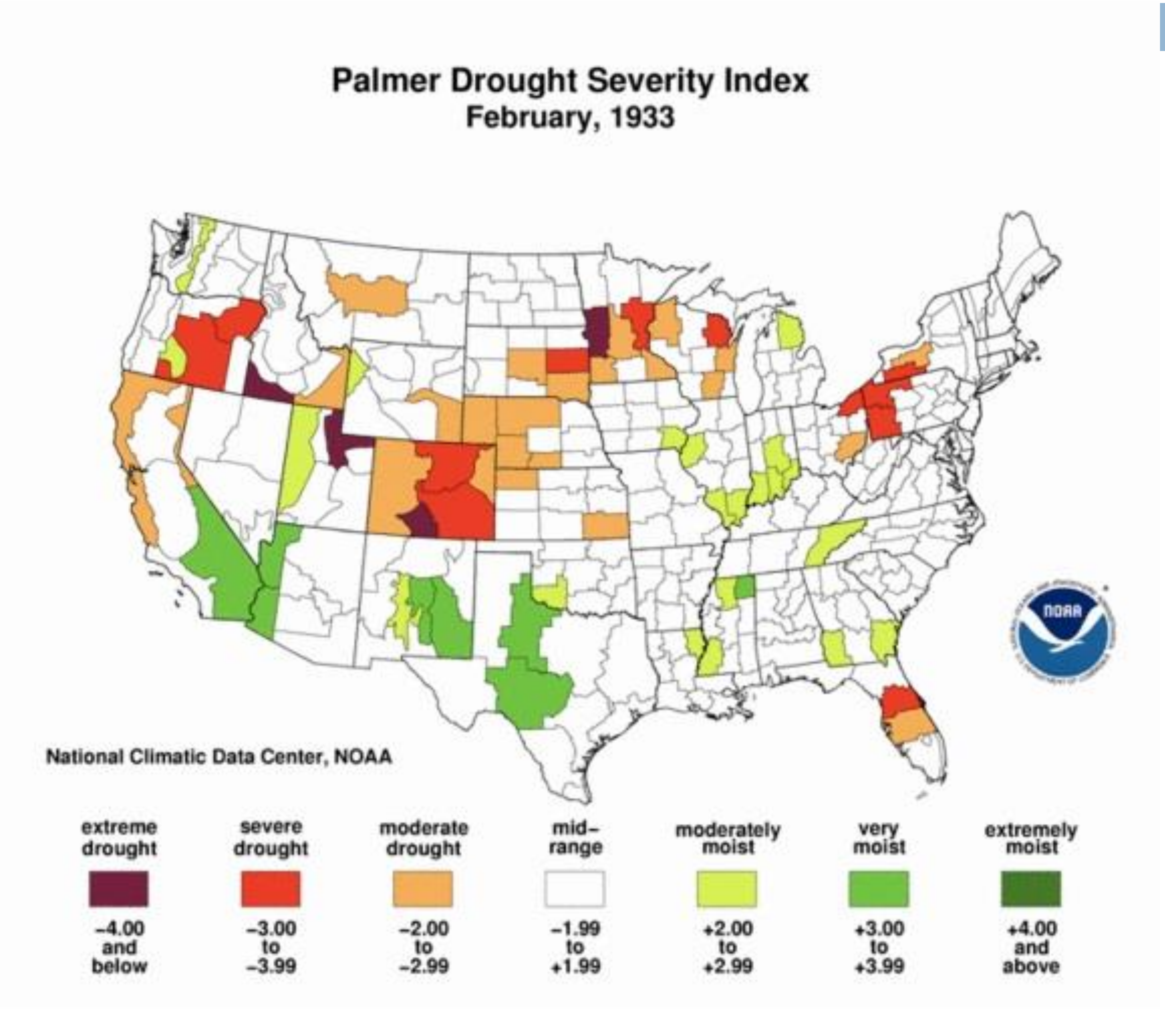
Disaster has overtaken a considerable part of Western Canada's wheat areas. Conditions in Manitoba and the southern parts of the province of Saskatchewan have become suddenly worse since three weeks ago, at which time the crops were described as the worst for 30 years.

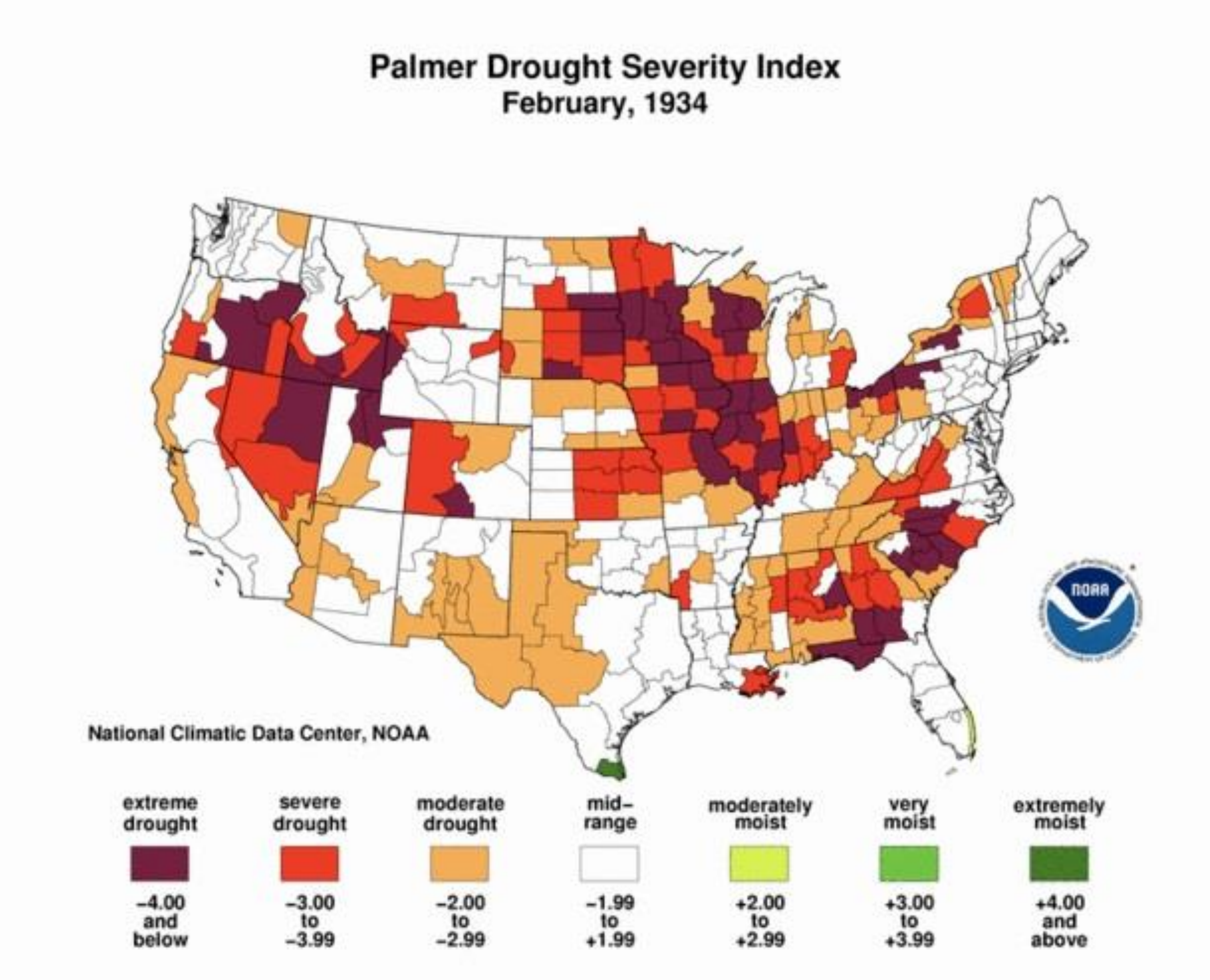
The extent of the wheat acreage totally destroyed is described as appalling.

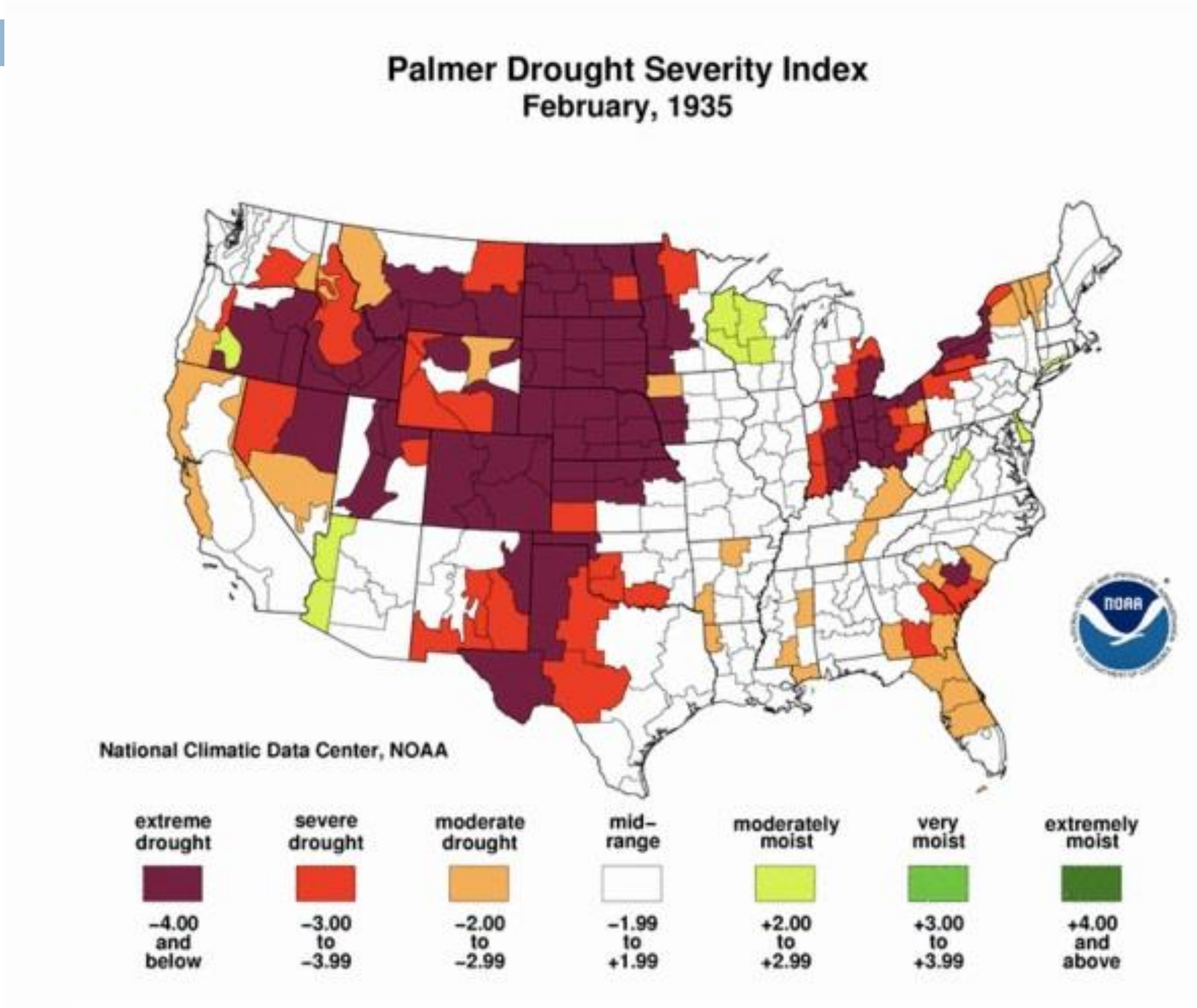
← 1931 : Worst Drought In Canada and US History

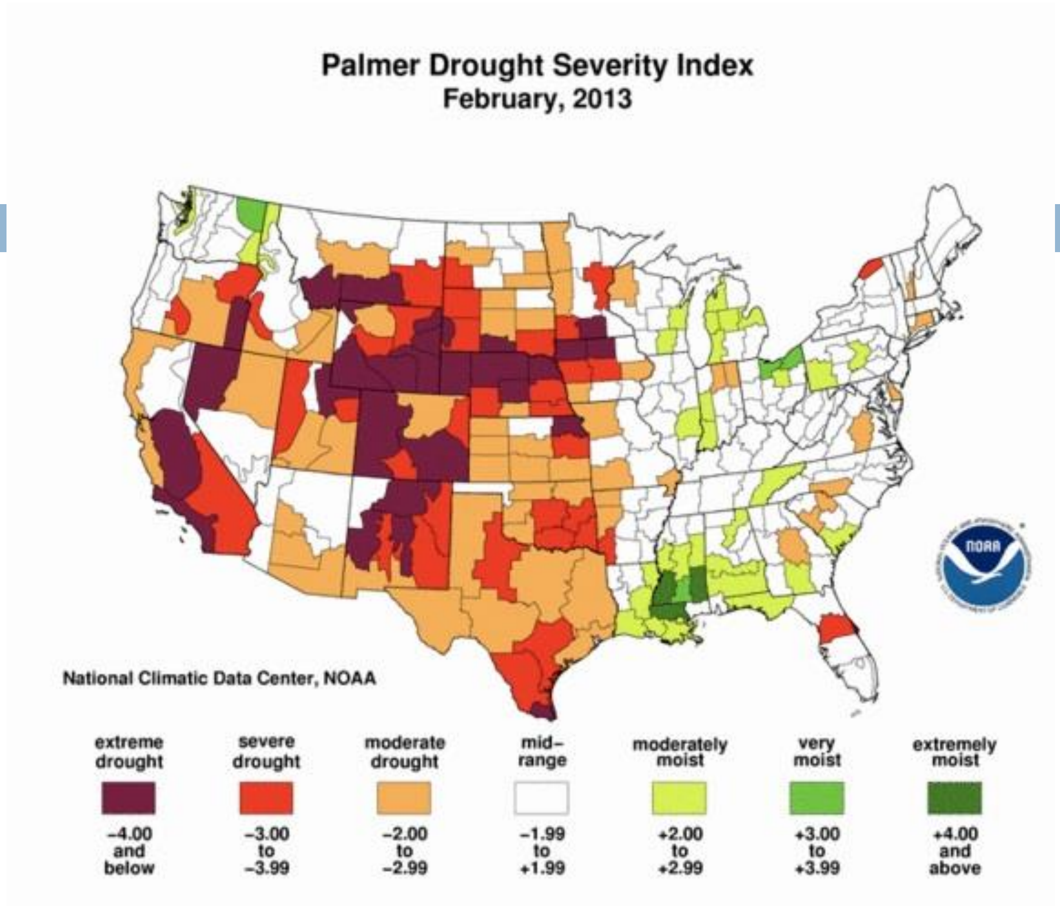
Figure 11.5 | Palliser's Triangle. *Source: Adapted from Bone (2005: 410).*

US Worst Drought in History (Dust Bowl, 1930s)




Palmer Drought Severity Index
February, 1934
National Climatic Data Center, NOAA
NOAA
extreme drought
severe drought
moderate drought
mid-range
moderately moist
very moist
extremely moist
-4.00 and below
-3.00 to -3.99
-2.00 to -2.99
-1.99 to +1.99
+2.00 to +2.99
+3.00 to +3.99
+4.00 and above


Palmer Drought Severity Index
February, 1935
National Climatic Data Center, NOAA
extreme drought
severe drought
moderate drought
mid–range
moderately moist
very moist
extremely moist
–4.00 and below
–3.00 to –3.99
–2.00 to –2.99
–1.99 to +1.99
+2.00 to +2.99
+3.00 to +3.99
+4.00 and above



With Drought Season Off to a Bad Start (in 2013), Scientists Forecast Another Bleak Year

Current climate-induced drought is slipping into a trend that scientists say resembles some of the worst droughts in U.S. history, like the Dust Bowl of the 1930s.

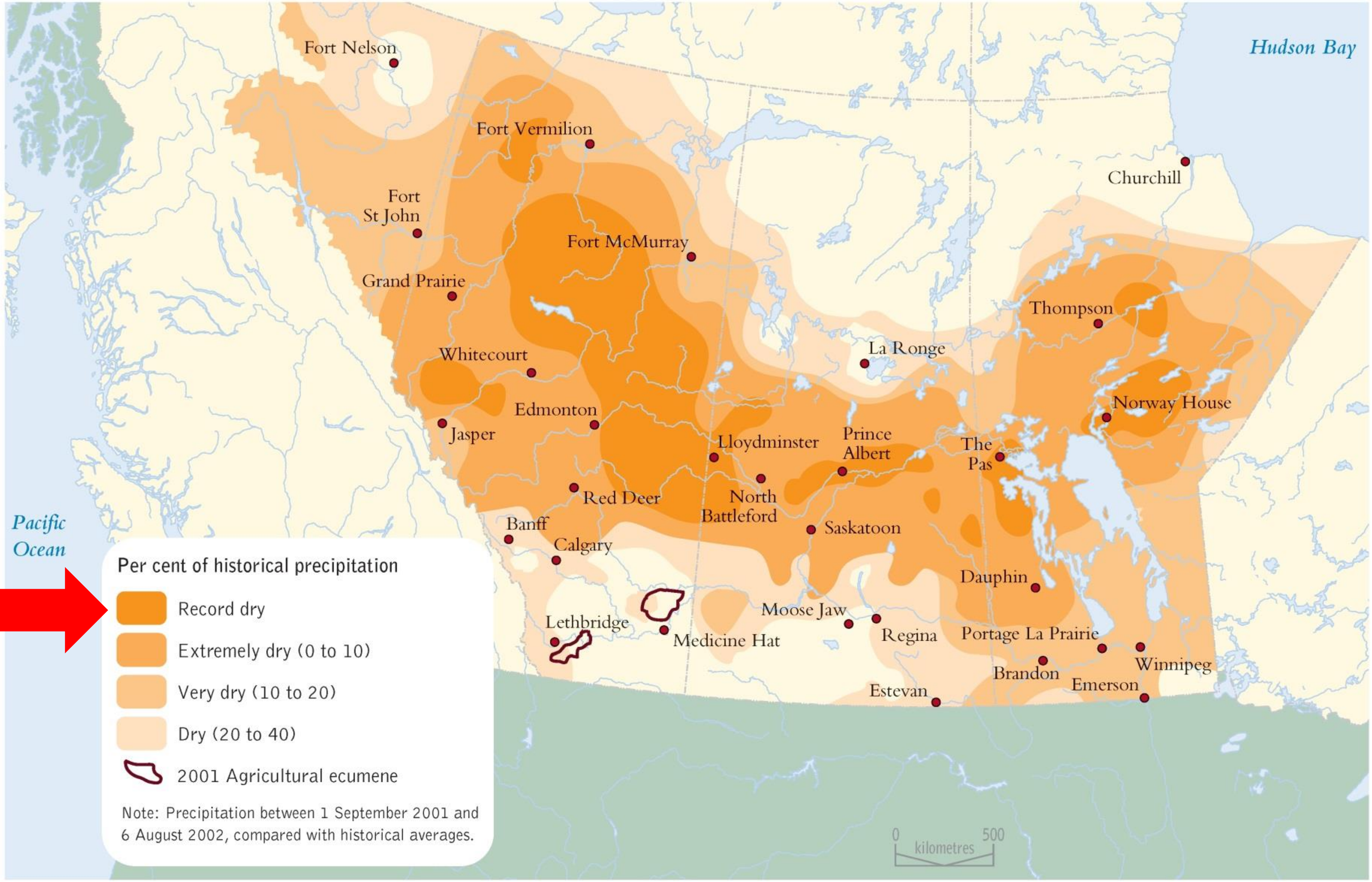
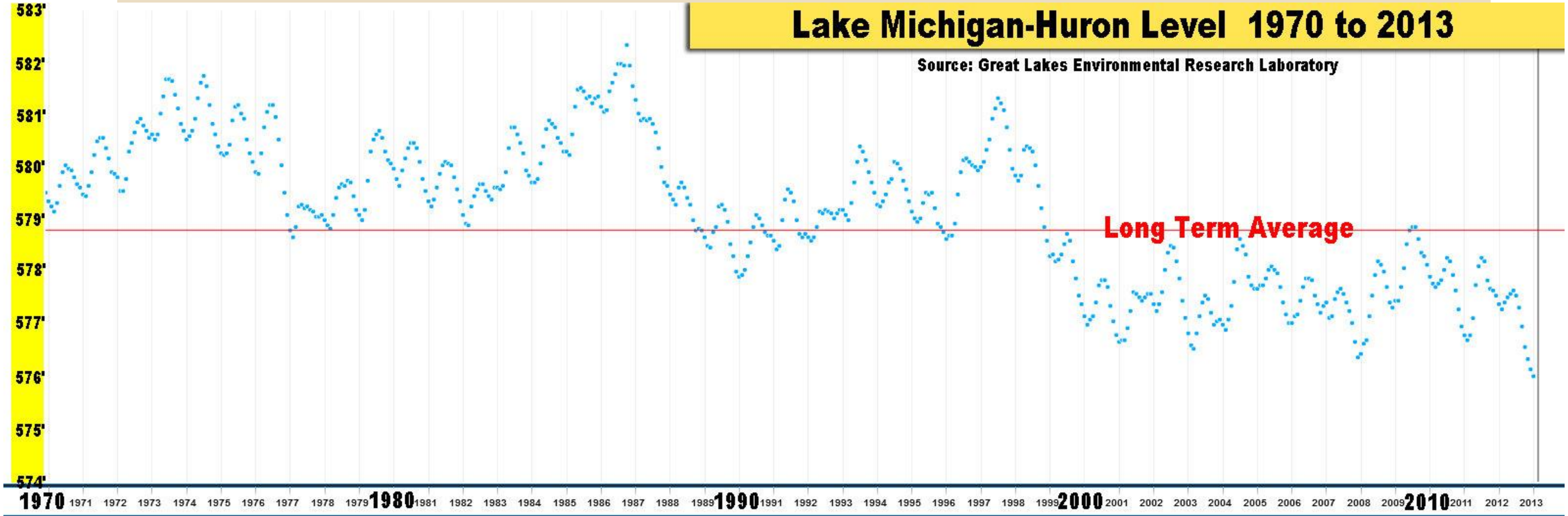


Figure 11.6 | Precipitation below historical averages, 2002. *Source: Statistics Canada (2003b: 13).*

Source: Dearden and Mitchell (2012)

Figure 11.6: Precipitation below historical averages, 2002 … more than ¾ of The Prairies affected

- In Ontario droughts are frequent during the growing season, but typically of short duration (10–20 days)
- Southwestern Ontario is particularly vulnerable
- Lake levels are affected by droughts (affecting shipping on the Great Lakes)
- During low rainfall periods, streams in Ontario are supplied entirely by groundwater discharges, thus groundwater depletion can have a serious impact on surface flows, as can a lowered water table



References

- Dearden, P and Mitchell, B. 2012. *Environmental Change and Challenge*, Fourth Edition, Don Mills, Ontario: Oxford University Press {Chapter 11: ‘Water’}