Rick Bowering
97/17

CWRA - ACRH

Canadian Water Resources Association
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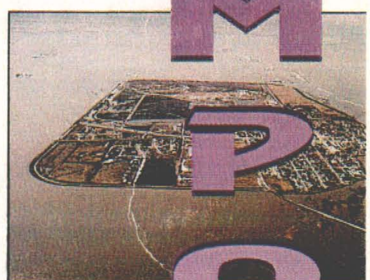
RED RIVER '97

THE FLOOD OF THE CENTURY

FLOOD SYMPOSIUM

CAUSES



IMPACTS

MANAGEMENT

October 22 & 23 1997
Winnipeg, Manitoba

PROCEEDINGS

OF THE

RED RIVER VALLEY
'97 FLOOD SYMPOSIUM

"The Flood of the Century"

October 22 & 23, 1997

WINNIPEG, MANITOBA
CANADA

Red River Valley '97 Flood Symposium
October 22 -23, 1997
Holiday Inn Airport West
Winnipeg, Manitoba

INTRODUCTION

The Red River Valley flood of 1997 was truly the "Flood of the Century". The impact on the infrastructure and lives of the people of the valley was significant. The flood levels achieved will result in the establishment of new standards for flood protection and flood mitigation works throughout the valley. The International aspects of the flood and the extensive media coverage have heightened the awareness for all citizens of the valley of the potential of devastating floods in the Red River basin. With a number of private and public agency remedial flood programs in place ,and an International Joint Commission study initiated, the time is ripe to share our experiences and capture the knowledge obtained to date.

This two day symposium disseminates and shares findings and knowledge of all aspects of the Red River '97 flood related to the causes, impacts and management of such an environmental event.

The symposium includes presentations developed around four major themes: Pre-flood Preparation, Fighting the Flood, Post-flood Activities, and the Human Element. A wide range of presenters from private citizens, to scientists, to politicians provide different perspectives on the "Flood of the Century" and how it affected the Red River basin.

The principle sponsor of this symposium is the Manitoba Chapter of The Canadian Water Resources Association. The symposium meets the aims and goals of the Association which are: to stimulate public awareness and understanding of Canada's water resources; to encourage public recognition of the high priority of water as a valued resource; to provide a forum for the exchange of information and opinions, relating to the management of Canada's water resources; and to participate with appropriate agencies in international water resource activity.

The Symposium's Planning Committee would like to sincerely thank all those individuals that provided assistance, including speakers and poster presenters. The Planning Committee would also like to acknowledge the kind contribution of funds to assist in hosting this symposium by the following agencies:

- NorWest Laboratories Inc.
- KGS Group
- Department of Natural Resources
- Linnet Geomatics

Organizing Committee

for

RED RIVER '97 FLOOD SYMPOSIUM
"The Flood of the Century"
Causes, Impacts, and Management

Chairperson -- John Towle - Manitoba Natural Resources

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RED RIVER '97 FLOOD SYMPOSIUM
"THE FLOOD OF THE CENTURY"
Causes, Impacts and Management

Holiday Inn Airport West
2520 Portage Ave.
Winnipeg, Manitoba

Program
Wednesday, October 22

Time	Program	Speaker
7:30	Registration and Coffee	
8:30	Opening Remarks	John Towle, Conference Chair
8:40	**Opening Address**	**Larry Whitney, Manitoba NaturalResources**

Session A - Pre-Flood Preparation

Time	Program	Speaker
9:00	Manitoba Flood Protection Works	Steve Topping, Manitoba Natural Resources
9:25	An Overview of Hydrologic Forecasting for the '97 Flooding in the US	Mike Anderson & Dean Braatz - U.S. National Weather Service
9:50	Flood Forecasting in Manitoba	Alf Warkentin - Manitoba Natural Resources
10:15	**Coffee**	
10:45	City of Winnipeg Flood Preparation	Doug McNeil - City of Winnipeg
11:10	Agricultural Flood Preparation	Gus Wruck - Manitoba Agriculture
11:35	Red River Valley Flood Preparation	Rick Hay - Manitoba Natural Resources
12:00	**Lunch**	

Session B - Fighting the Flood

Time	Program	Speaker
1:00	Emergency Construction of Z dike	Guy Cooper- Manitoba Highways
1:25	Flood Management Task Force	Jay Doering - U of Manitoba
1:50	City of Winnipeg	Barry McBride - City of Winnipeg
2:15	**Coffee**	
2:45	MEMO - Coordination & Decision Making Process	Harold Clayton- MEMO
3:10	Emergency Preparedness Canada Role	Larry French - Emergency Preparedness Canada
3:35	Canadian Armed Forces	Major BrianFlynn - DND
4:00	Federal Government Post Flood Activities	Bill Carrothers - Federal Business Restoration Office
4:25	Wrap up	John Towle - Conference Chair
4:40	**Wine & Cheese Reception**	

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RED RIVER '97 FLOOD SYMPOSIUM
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Program
Thursday, October 23

8:30	**Keynote Address**	**Mayor Susan Thompson - City of Winnipeg**

Session C - Post-flood Activities

8:50	Flood Damage Assessment	Joe Masi - Manitoba Government Services
9:15	Environmental Impacts	Dwight Williamson - Manitoba Environment
9:40	Impacts on Groundwater	Rick Lemoine - Manitoba Environment
10:05	**Coffee**	
10:30	Treatment of Surface Dugouts	Rob Butler - PFRA
10:55	Assessment of NWS Hydrologic Models	Mike Anderson & Dean Braatz - U.S. National Weather Service
11:20	Manitoba Flood Proofing Program	Chuck Whalen - Manitoba Natural Resources
11:45	Research Initiatives	Robert Tait - Disaster Research Institute
12:10	**Lunch**	

Session D - the Human Element

1:15	Roseau River First Nation Experiences	Felix Antoine
1:40	Turnbull Drive Dike	Norm Hunter
2:05	Kingston Crescent Dike	Ed Kuiper
2:30	**Coffee**	
2:55	Red River &LaSalle Valleys	Dave Woytowich
3:20	Canadian Red Cross	Jackie Wright - Regional Director
3:45	Peoples' Participation in Emergency	Matiur Rahman - Disaster Research Institute
4:10	Media Perspectives	Iris Yudai - CBC radio
4:35	Closing Remarks	John Towle - Conference Chair

Program
Friday, October 24

8:30 Tour of the Red River Valley

PRESENTED PAPERS

Session A - Pre-Flood Preparation

Session B - Fighting the Flood

Session C - Post-Flood Activities

MEMO - Damage Assessment (*Joe Masi*)

Environmental Impacts (*Dwight Williamson, Colin Hughes and Edward Sorba*)

Rehabilitation of Microbiologically Contaminated Groundwater Resulting from the 1997 Red River Flood - Grande Pointe Case Study (*Rick M. Lemoine and Jennifer L. Corkery*)

Coagulation Treatments for Flooded Dugouts (*Robert Butler and Darrell Corkal*)

Assessment of National Weather Service Hydrologic Models and Forecasts for the Red River of the North (*Micheal E. Anderson and Dean T. Braatz*)

Flood Proofing Program: Home Business and Community (*Chuck Whalen*)

Research Initiatives (*Robert W. Tait*)

Session D - The Human Element

Turnbull Drive/Red River Drive Dike (*Norman R. Hunter*)

The Kingston Crescent Dyke Surrounding The Elm Park Peninsula Community (*Ed Kuiper*)

Of Water and Water Fighters: Peoples Response to Flood-1997 in the Red River Valley, Manitoba: A Research Agenda (*Matiur Rahman*)

Media Perspectives (*Iris Yudai*)

RED RIVER VALLEY FLOOD CONTROL WORKS AND RELATED INFRASTRUCTURE IN THE PROVINCE OF MANITOBA, CANADA

Steven D. Topping[1], P. Eng.

The Red River Floodway is the major project in a flood control program on the Red and Assiniboine rivers constructed between 1962 and 1972 in the Province of Manitoba, Canada. The Floodway, in conjunction with the Portage Diversion and the Shellmouth Dam on the Assiniboine, and a primary diking system, provides flood protection to the City of Winnipeg.

The two projects on the Assiniboine River, in addition to reducing flood levels in Winnipeg, provides protection to the cities of Portage la Prairie and Brandon and an estimated 161,878 hectares of land along the Assiniboine River in Manitoba.

Description of Basin

Winnipeg is located at the junction of the Red and Assiniboine rivers approximately 97 kilometres upstream of Lake Winnipeg into which the Red River discharges. The Red River rises near the Town of Whapeton, North Dakota, approximately 402 kilometres south of Winnipeg and flows northerly on a gentle slope averaging 0.01 percent.

The total drainage area of the Red River at Winnipeg is 287,490 square kilometres. The Assiniboine River drainage area represents 163,170 square kilometres of this total, however, the topography and climate of the Assiniboine Basin are such that the maximum flow is much less than that of the Red River with its 124,320 square kilometres of drainage area.

Historical Floods

The 1997 flood event was the largest recorded in the 20th century in the Red River Basin. The previous largest flood event on the Red River, in this century occurred in 1950. The peak discharge recorded on the Red River downstream of the Assiniboine River in 1950 was 3,057 cubic metres per second (cms) while the unregulated discharge (the flow which would occur in the absence of the flood control works on the Red and Assiniboine rivers in Manitoba) estimated on the Red River downstream of the Assiniboine River was 4,586 cms on May 4, 1997.

The largest recorded flood event on the Red River in the 19th century was in 1826 at 6,370 cms. Then in 1852, another flood occurred with a recorded discharge of 4,671 cms.

Other flood events that are significant in magnitude occurred in 1861 at 3,539 cms, in 1996 at an unregulated discharge of 3,057 cms and in 1979 at an unregulated discharge of 3,029 cms.

Description of Projects

Following the 1950 flood on the Red River, the federal government, together with the Province of Manitoba, set up a fact-finding commission to appraise the damages and make recommendations. The commission recommended in 1958 the construction of the Red River Floodway, the Assiniboine (Portage) Diversion and the Shellmouth Reservoir.

The Red River Floodway

- The Red River Floodway consists of four major components:
  The Inlet Structure
  The Floodway Channel
  The Outlet Structure
  The East & West Dikes

- The inlet structure is located in the Red River channel just a short distance downstream from the Floodway inlet. The structure has two submersible gates, each 34.3 metres wide, which, under non flood conditions, remain at the level of the channel bottom. In times of flood, the gates are raised to control the division of flow through the City of Winnipeg and the Floodway channel.

- The Floodway channel, which provides a partial rerouting of the Red River, has a design capacity of 1,700 cms and an emergency capacity of 2,830 cms. It is 46.7 km long with an average depth of 9.1 metres and an average bottom width of 137.2 metres. Seventy-six and half million cubic metres of earth were excavated making it the largest excavation project ever undertaken in Canada.

- The outlet structure is a concrete drop structure located just downstream of Lockport. At this location, under design discharge conditions, there is a drop in water surface from the Floodway to the Red River of about 4.3 metres. The outlet structure is required as an energy dissipator that prevents downstream scour and erosion as the Floodway water re-enters the Red River.

- Dikes are required to prevent flood water from passing downstream through the City of Winnipeg. On the east side of the Red River, the dike has been incorporated into the construction of the floodway channel. On the west side of the river, the dike was built a distance of about 34 km westerly from the inlet structure to tie into higher ground.

- Construction was completed in 1968.

Portage Diversion

The major elements of the project are the diversion dam in the Assiniboine River, the concrete spillway control structure, the inlet control structure in the diversion, the diversion channel itself, two gradient control structures and an outlet structure.

- The Portage Diversion is a 29 km long channel designed to carry flows up to 708 cms away from the Assiniboine River and into Lake Manitoba.

- Construction was completed in 1970.

Shellmouth Dam and Reservoir

- The dam is about 21 m high and 1,270 m long. It has a reinforced concrete horseshoe-shaped conduit 4.6 m in diameter by means of which reservoir releases are made. Flood flows in excess of conduit capacity are passed over a concrete chute spillway. Construction was completed in 1972.

- The reservoir created by the Shellmouth Dam is approximately 56 km long and is capable of storing 863,398 m^3 of water. The protection afforded by the reservoir extends over the entire reach of the Assiniboine River between the Shellmouth Dam and its influence with the Red River at Winnipeg. Cities other than Winnipeg which benefit by not only flood reduction but also low flow augmentation, are Brandon and Portage la Prairie.

Red River Valley Community Dikes

During the flood of 1966, negotiations between Manitoba and Canada were undertaken which ultimately culminated in the Federal Government agreeing to share in the cost of flood fighting, restoration of flood damaged roads, bridges and drains, repairing of houses, farm buildings and other small business properties damaged by the 1966 Red River Valley flood. In addition, the Federal Government agreed to share in the cost of permanent diking in the Red River Valley. Permanent diking consisted of not only community diking of towns in the Red River Valley but also protection of farmsteads in the valley by either construction of ring dikes or by raising the foundations of farm buildings.

The eight communities included in the agreement were Emerson, Letellier, Dominion City, St. Jean Baptiste, Morris, Rosenort, Brunkild and St. Adolphe.

Following the 1979 flood, the diking systems were upgraded to provide protection to the 100 year flood level.

Operation of Flood Control Works

During the 1997 flood of the century event, new milestones were reached within the flood control works. The Red River Floodway diverted flows around the City of Winnipeg from April 21 to June 3, 1997. The floodway's peak discharge occurred on May 4, 1997 at 1,840 cms. The previous highest peak discharge was 1,127 cms on May 9, 1979.

The Portage Diversion operated from April 3 to May 30, 1997 with a peak discharge estimated on April 20th, 1997 at 538 cms.

The Shellmouth Dam and Reservoir reduced the flows along the Assiniboine River by allowing only a peak outflow of 46 cms on May 20 and 21, 1997. The peak inflow to the reservoir was recorded at 283 cms on April 27 and 28, 1997.

In the Red River Valley, the eight ring-diked communities became island fortresses at the height of the flood. These communities stayed dry through the flood of the century.

The west dike of the floodway inlet control structure, which prevents flood waters from bypassing the structure and entering the City of Winnipeg, had to be extended and raised to deal with this large flood event. More than 400 pieces of heavy equipment worked 24 hours a day for five days to construct 25 kilometres of new dike. Another 15 kilometres of the existing west dike was reinforced.

Conclusions

The Red River Valley flood control works and related infrastructure in the Province of Manitoba performed very well in managing the flood of the century.

The decision to construct these works was a wise one. The Floodway has been used 20 times in 18 years since it was opened in 1969. It is estimated that it has prevented over $3.1 billion in damage to the City of Winnipeg in 1997 dollars based on the level of development in 1957.

1. Director, Water Resources Branch, Manitoba Natural Resources, Winnipeg MB

Mike Anderson

ice control - dusting the river ice

Gr Forks

Flow Forecast for G. Forks was good

Big problem was rating curve - error of 4 ft on peak!

Many communities ring dyked.

An Overview of Hydrologic Forecasting for the 1997 Record Flooding on the Red River of the North in the United States

Michael E. Anderson P.E., Hydrologic Forecaster
Dean T. Braatz, Hydrologist In Charge
NOAA, National Weather Service *
North Central River Forecast Center
Chanhassen , Minnesota , U.S.A.

INTRODUCTION

The Red River of the North experienced record flooding in April 1997 from a combination of excessive snow depths and a major blizzard which occurred during the snowmelt period. Above average snowfall and wet ambient soil moisture contents provided conditions conducive to severe flooding. Snowmelt Flood Potential Outlooks predicting record flooding were issued two weeks earlier than normal by the National Weather Service's North Central River Forecast Center (NCRFC) to convey the severity of the situation. Despite massive flood fighting efforts, tens of thousands of people had their lives interrupted and as much as two billion dollars of damages were incurred. This discussion briefly summarizes the flood event, highlights a few of the major forecasting difficulties encountered during the flood, and provides preliminary findings and recommendations from post flood analysis.

THE BASIN WITHIN THE UNITED STATES

The Red River of the North is formed at the confluence of the Ottertail and Bois de Sioux rivers at Wahpeton, North Dakota, in the extreme southeast corner of the state. It maintains a northerly course for 240 kilometers, dividing the states of Minnesota and North Dakota, to its crossing at the Canadian border (Figure 1). It was named the Red River of the North to distinguish it from the Red River in the southern United States, a tributary of the lower Mississippi River. Henceforth, it will be referred to as the Red River.

The Red River is a very young river geologically and it lacks a well defined, incised channel. It is characterized by a highly sinuous channel of extremely low slope. The wide, flat "river valley" was not formed by river processes but was created by glaciers. The channel flows across what is the

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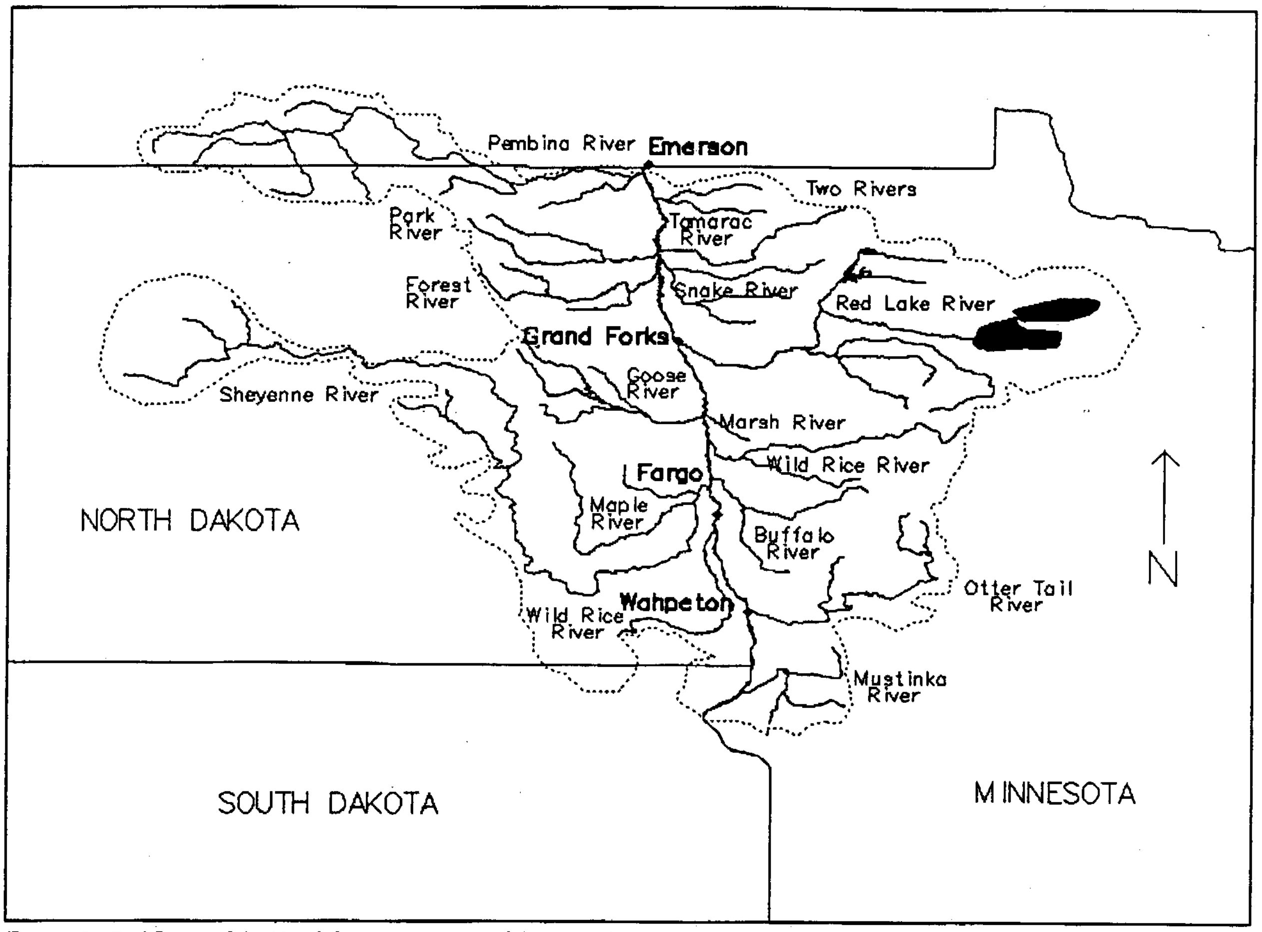

Figure 1. Red River of the North basin upstream of the Canada-U.S. border.

former lakebed of glacial Lake Agassiz, once the largest body of fresh water on earth. The slope of the mainstem Red River ranges from 0.2 meters per kilometer near the headwaters to only 0.1 meters per kilometer at the international boundary (Miller and Frink, 1984). Extensive drainage networks have been constructed in the basin over the past several decades to promote rapid runoff from agricultural fields.

Historically the greatest floods on the mainstem Red River are produced from spring snowmelt runoff. This is primarily because the river flows to the north, intensifying flooding as the mainstem crest normally arrives with the advance of warmer temperatures. Thus, upstream flow contributions, local snowmelt runoff, and the breakup of river ice all coincide as the flood progresses through the valley. These conditions maximize the flow concentration as the river continues on it's northward course.

At the international boundary the basin drainage area encompasses more than 100,000 square kilometers. Channel capacities range from 99 cubic meters per second (cms) at Wahpeton, North Dakota to 991 cms at Pembina, North Dakota. Once channel capacity is exceeded, floodwaters flow relatively unrestricted by natural topographic barriers in the valley. The low gradient of the surrounding terrain allows floodwaters to spread over an extensive area, as the entire valley acts as the primary floodplain. During very large events, such as experienced in 1997, significant volumes of meltwater can travel as overland flow.

1997 BASIN CLIMATOLOGY

The stage was set for record flooding in the spring of 1997 by a combination of wet ambient soil moisture conditions and extremely heavy winter snow depths. Winter precipitation totals ranged from 125% to over 200% of normal, with the heaviest amounts in the upper half of the basin. For example, the average seasonal snowfall at Fargo is only 953 millimeters but this year's total was a record 2,867 millimeters . Winter temperatures were also colder than normal, with no intermittent winter melt. Temperatures remained cold until mid to late March when very warm conditions initiated a rapid snowmelt. The melt was interrupted by a late season blizzard during April 5th-7th, which brought a combination of freezing rain and snow to the region. This storm produced widespread water equivalent amounts up to 61 millimeters over the entire southern half of the valley. This added significant runoff volume, increasing water equivalents to over 200 millimeters in parts of the basin.

FLOOD OUTLOOKS

A series of Spring Flood Outlooks are issued by the NCRFC every year during February and March. These products are designed to provide advance guidance of spring snowmelt flood potential. The first product of the season is normally issued in late February. However this year the NCRFC began issuing products two weeks early due to the heavy winter snow pack. The initial February 13th outlook called for "severe snowmelt flood potential" along the Red River. The severe category is defined as "crests from near record levels to exceeding record levels". This forecast persisted in subsequent outlooks until the final product of the season was issued on March 22nd. Forecast verification shows that the original February stage forecast was quite accurate considering a six week lead time. The mean absolute error of the original basin outlook was 0.5 meters, which was prior to the April blizzard and additional precipitation that came with it.

BLIZZARD EFFECTS

The April blizzard created many forecast difficulties at the NCRFC . Little observed precipitation data was available from this event for several days due to the loss of power and communication networks through the region. Forecasters at the NCRFC relied heavily on airborne surveys by the NWS National Operational Hydrologic Remote Sensing Center (NOHRSC) following the storm. These surveys collect snow water equivalent data by measuring gamma radiation along established flight lines. Survey data are processed into basin average values for use as NCRFC forecast model input. The NOHRSC conducted an emergency survey of the Red River basin at the request of the NCRFC during April 9th-12th. Data from this survey was immediately processed and available to forecasters by the morning of April 14th. However, this left little time to revise forecasts at sites already approaching a crest, especially at Fargo and Grand Forks where river levels were already threatening to overtop sandbagged levees.

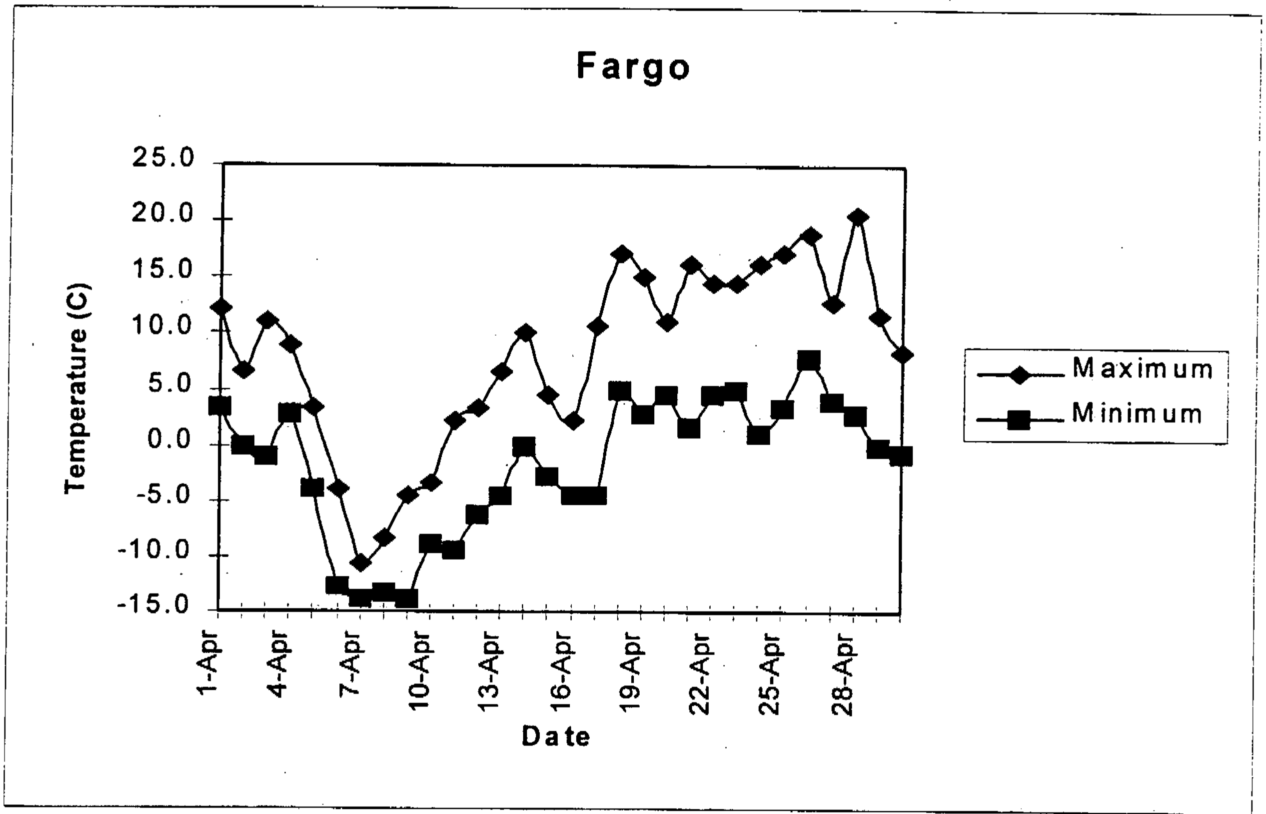

Figure 2. Temperatures for the month of April at Fargo, North Dakota. The April blizzard occurred from the 5th to the 7th.

The ensuing cold period following the storm halted the normal melt pattern and created further difficulties in producing accurate and timely flood predictions (Figure 2). As much as 196 millimeters of water equivalent remained in the basin after the initial melt period. An unexpected rapid warming trend occurred a few days later, causing the resumption of snowmelt and an influx of runoff.

As the snowmelt resumed, highways and other roadbeds functioned as dikes, providing temporary barriers to overland flow and causing fields to act as small reservoirs. As these reservoirs reached their capacity, runoff would overflow the lowest point of the road grade into an adjoining field. This process continued in a checkerboard fashion across the valley, allowing much of the runoff to bypass the normal drainage network. This pattern occurs every year to some extent, however, overland flow characteristics observed this year were different than in past floods. Local county roads had little influence on runoff, and only major highway road grades provided any significant flow controls (Lejcher, 1997). The magnitude of this flood is perhaps best demonstrated by some of the public reports received by the NWS. Numerous observations from life long residents indicated water flowing overland where it was never seen before.

MODELING COMPLEXITIES

Numerous forecasts were developed using rating curve extensions beyond observed values due to the magnitude of this flood. The forecast model (NWSRFS) is designed to automatically extend ratings by logarithmic extrapolation in these cases.

Initial forecast model accuracy was compromised to a limited extent by numerous channel breakouts and inter-basin flow transfers. Extensive field reconnaissance by supporting agency field personnel provided location and flow data from these breakouts. Field measurements were made, where possible, of overland flows, typically at road overflows. Forecasters used this information to monitor the flow volume as it moved across basins. They then adjusted simulated hydrographs by manually balancing flow volumes at specific locations according to these reports. Model accuracy was improved in this manner to more closely reflect what was actually occurring in the basin.

The complex network of drainage ditches and conduits in the basin remained frozen after the snowpack melted, complicating matters. This further altered normal runoff patterns, retaining water in the fields and intensified overland flooding. Forecasters manually corrected the model for this effect by delaying the simulated melt of the snow pack until drainage networks had opened.

FLOOD CRESTS

Resulting river crests shattered previously recorded levels at 18 of 34 forecast locations in the Red River basin. Of the 16 remaining forecast points, 4 tied the record and 3 crested within 0.3 meters of the record. Crests averaged 0.3 to 0.7 meters above record levels along the mainstem reach

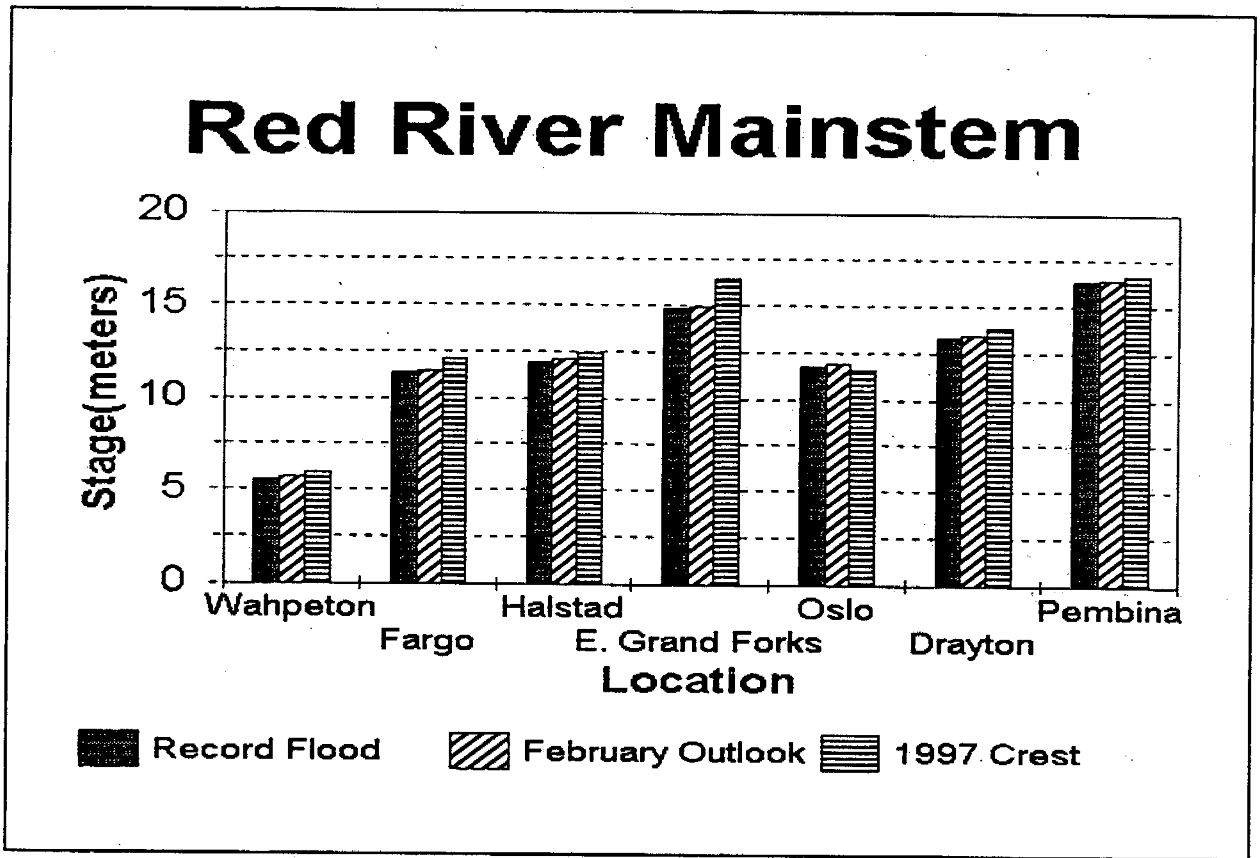

Figure 3. Stage comparisons on the mainstem Red River. Forecast stages are from the February 27th Snowmelt Outlook

of the Red River (Figure 3). Massive flood fighting efforts were undertaken in 34 different communities by the time the crest reached the international boundary. Only four of these towns suffered significant flood damage, the most notable of which was the Grand Forks-East Grand Forks area where levees were inundated by valley slope backwater and bridge induced backwater effects. Several communities were surprised by flooding from overland flow, in addition to the mainstem river flooding.

Extensive coordination and cooperation between the North Central River Forecast Center, the United States Geological Survey, the United States Army Corps of Engineers, the Minnesota Department of Natural Resources, and numerous local authorities was instrumental in preventing further damage and loss of life in the valley. Coordination with Manitoba Water Resources staff in Winnipeg, Canada was ongoing throughout this event.

FLOOD FORECAST SYNOPSIS OF EAST GRAND FORKS

As early as April 14th, forecasters predicted a peak discharge of 3,115 cms to occur on April 22 at East Grand Forks. The flow at the time the peak stage occurred was 3398 cms on April 22.

The observed peak flow of 3,835 cms occurred on April 18th, as the communities of Grand Forks and East Grand Forks were inundated by the flood. Damages in the area were by far the most significant aspect of this flood, producing catastrophic results. A post flood site investigation by USGS, USACE, and NWS personnel was conducted the week of May 1st to find out what caused the abnormally large forecast error at this location. Among other findings, the survey team discovered that a containment levee break on an *ungaged* tributary occurred during the late evening hours of April 17th, continuing through the very early morning hours of April 18th. This correlated closely with the timing of the peak flow measurement. This tributary channel flowed through East Grand Forks to its confluence with the Red Lake River just upstream of the East Grand Forks gage. USGS specialists concluded through indirect measurement techniques that this inflow was approximately 700 cms (Wicke, 1997). Had this unpredictable event not occurred the simulated peak discharge would have been very accurate. Therefore, although forecasters had accurately predicted the peak flow at Grand Forks, the stage-discharge relationship was the major source of error in the forecast (the forecast had an abnormally high error of 1.3 meters). In light of this fact, NWS interagency forecast products should include both flow and stage data in the future to provide the most complete information possible to other agencies.

SUMMARY AND CONCLUSIONS

The flood of 1997 tested the limits of current science and technology used by the NWS for flood forecasting. Forecast verification demonstrated that the forecast system functioned well overall, providing adequate forecasts and preventing widespread flood damage. However post-flood analysis has identified several key problems encountered during the course of this event which deserve further attention.

>>> The breakup of river ice and resulting ice jams is a perpetual problem in real time river forecasting. This flood was no exception, as ice jams were responsible for significant flooding at some locations. Furthermore, the persistence of ice in drainage ditches and other conduits after active snowmelt produces great difficulty in predicting the timing of runoff. Further model refinements are needed to account for the temporary storage of snowmelt before ditches and conduits have opened up.

>>> Rating curves used during this flood relied on simple extrapolation techniques beyond observed values. This proved to be a significant source of error at more than one location. Measurements taken during the crest indicated as much as one meter shifts in ratings above previously recorded flows (Figure 4). Although the NWS is the official source of river forecasts in the United States, it relies on other agencies to provide much of the information used in forecasting. For instance, the USGS is responsible for maintaining automated river gages and developing site rating curves. The

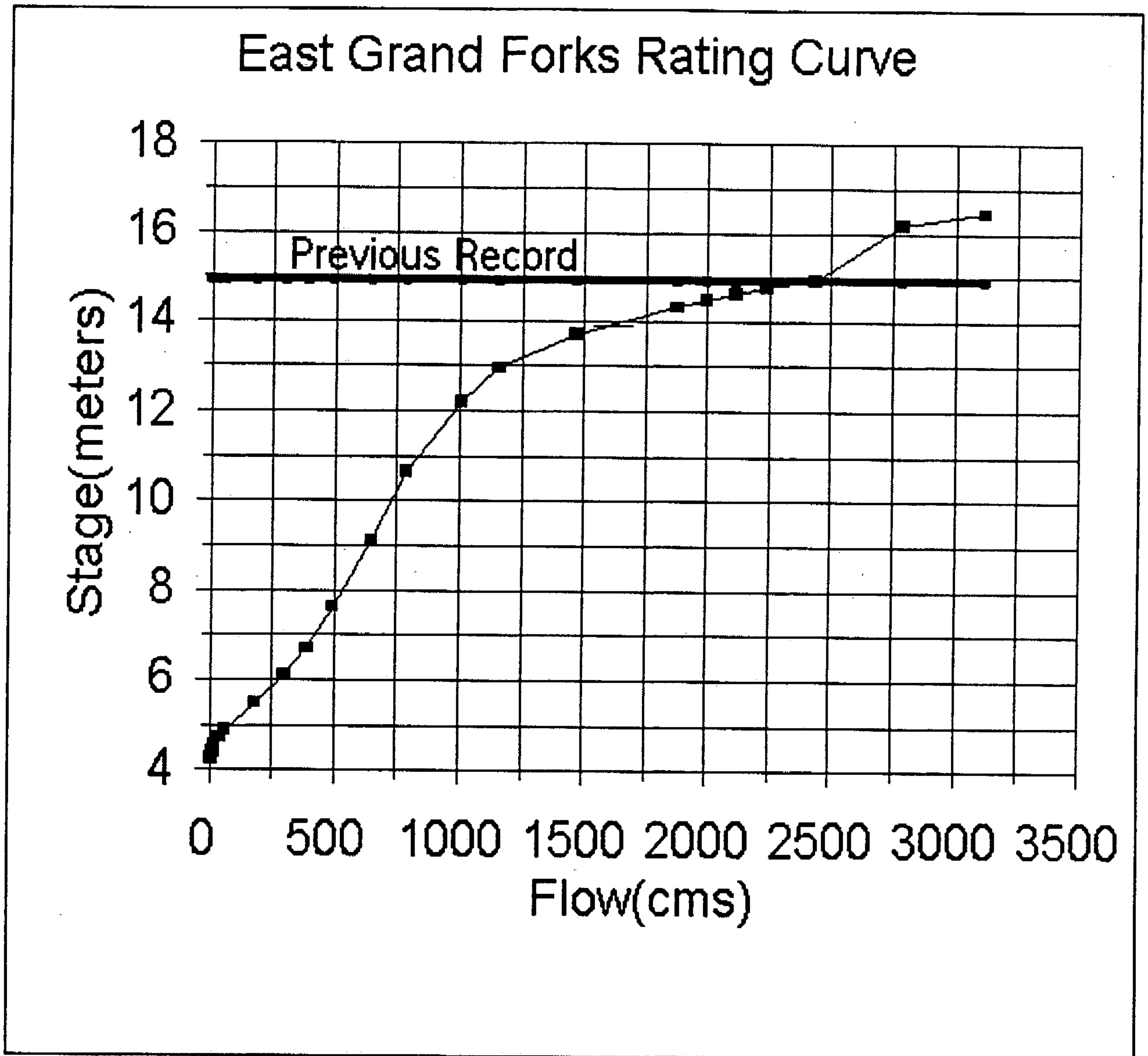

Figure 4. Rating curve from the East Grand Forks forecast location. The top two data points are from measurements taken during the flood this year. Notice the shift above the previous level.

USACE maintains information on levee elevations, and develops Flood Insurance Studies (FIS) for communities which contain valuable hydraulic and structural information. Annual interagency reviews need to be conducted to coordinate the sharing of this information among all users. This will ensure the accuracy of current rating extensions, identify sites with loop ratings, and provide information on bridge structures.

>>> The gage location at Grand Forks/East Grand Forks has changed since the previous record crest to a location upstream of the previous site. River profile analysis indicates that this location differs by as much as 0.7 meters in stage elevation at a given flow. Therefore, direct comparison of this years event to the previous record stage and is not accurate. Critical data was also lost when gages were damaged or inundated by the high water. Future gage installations should insure that the gage equipment is installed above the probable maximum flood elevation to avoid losing data during the heighth of a flood.

>>> Real time hydraulic routing techniques are needed to accurately simulate the effect of levee breaks during a flood. Levees as high as 7.6 meters were breached during this event, causing dramatic changes in flow characteristics. Other off-channel levee breaks were responsible for contributing major inflows into the mainstem river channel during the crest. The ability to accurately detect and model off channel storage and flow is needed in floods of this magnitude on the Red River.

>>> The lack of dynamic routing techniques in the forecast model prevented forecasters from predicting the effect of bridges in the Grand Forks reach. Given the unsteady flow conditions that commonly occur on the Red River, dynamic routing would more accurately simulate actual conditions than the current lumped flow model (Fread, 1992) . It could also be extended to potentially predict inter-basin flows by including topographic features.

>>> An interagency post-flood disaster survey determined that the difference between the Snowmelt Outlook Flood Potential products and operational forecasts is not well understood by users. Many users interpreted the outlook values to be the actual operational crest forecast. Issuing two sets of outlook values, one with normal future conditions and one with no future precipitation input, further confuses the situation. Users tend to view these values as possible crest range limits. When soliciting users as to what type of information would be more valuable, there is no clear consensus. The NOAA Disaster Survey concluded that implementing the Extended Streamflow Prediction (ESP) technique on the Red River Basin would provide additional useful information to the users. This system produces long term probabilistic forecasts over a range of flows by combining the conceptual modeling component of NWSRFS with climatological information through stochastic modeling techniques. (Day, 1985) The need for a more simplistic "single" outlook crest, including normal precipitation, was the overwhelming response from community officials attending the Red River Valley Post Flood Community Meetings, (Anderson, 1997).

REFERENCES

Anderson, Michael E., 1997: Red River Valley Community Post Flood Meetings, (Wahpeton, Fargo, Grand Forks, Northern Valley).

Day, Gerald N., 1985: Extended Steamflow Forecasting Using NWSRFS, Journal of Water Resources Planning and Management, Vol. 111, No. 2, pp. 157-170.

DeWeese, Michael M., 1997: The Record Floods of 1997 on the Red River of the North in the United States: A Case Study. To be published as a proceedings document from the special session: The 1997 Red River Flood, International Water Resources Association World Congress, September 1-6, 1997, Montreal, Quebec, Canada.

Fread, D.L., 1993, Flow Routing, In Maidment, David R., Handbook of Hydrology, McGraw-Hill, Inc., New York, U.S.A., ISBN 0-07-039732-5, pp. 10.1-10.36.

Lejcher, Terry, 1997, Significant Events in Bois de Sioux and Ottertail River Watersheds During April 1997 Flood, Minnesota Dept. of Natural Resources written report to North Central River Forecast Center, available from Minnesota Dept. of Natural Resources, Fergus Falls, Minnesota.

Miller, Jeffrey E. and Frink, Dale L., 1984, Changes in Flood Response of the Red River of the North Basin, North Dakota-Minnesota, USGS Water Supply Paper 2243, Supt. Of Doc.s no. I 19.12.2243.

Wiche, Greg, 1997, personal communication, United States Geological Survey, Bismark, North Dakota.

THE RED RIVER FLOOD OF 1997

An Overview of the Causes, Predictions, Characteristics and Effects of the Red River Flood of the Century

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July 4, 1997

The Red River Flood of 1997

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Abstract

The 1997 spring flood on the Red River in Manitoba was the highest recorded this century. Peak stages from the United States Boundary to the Red River Floodway Control Structure just south of Winnipeg were 0.6 to 1.5 metres higher than for the great floods of 1950 and 1979. Levels in downtown Winnipeg were 1.5 metres higher than for any flood since 1969 when the Red River Floodway went into operation. Use of major flood control works reduced the peak stage in Winnipeg by 3.0 metres. Total flood damages will likely exceed $200 million while damages prevented by flood control works and emergency diking is estimated at over $6 billion.

At least 1840 square kilometres of valley lands were flooded as the Red River rose 12 metres above winter levels. Eight valley towns with ring dikes remained dry and the City of Winnipeg sustained little damage due to flood control works and emergency diking. However, one town, one hamlet and numerous farm properties in the valley were seriously flooded.

The main cause of the 1997 flood was an extreme snowpack which was at the 98th percentile level. Other factors included high topsoil moisture due to heavy fall rains in 1996, and unfavourable timing of runoff from major source areas in the basin. A major storm in early April, spawned in Colorado, added greatly to the flooding by dumping 50 to 90 mm of water in the form of rain (south) and snow (north). Winter precipitation was likely underestimated due to numerous snowstorms with strong winds. Airborne gamma snow surveys indicated a record high water content of the snowpack

Red River Flood of the Century

Antecedent Conditions

The Red River in Manitoba had experienced a minor flood in 1995 and a significant flood in 1996, the latter having peak stages only one foot or so lower than the 1979 and 1950 floods. The summer following the 1996 flood was relatively dry which seemed to be a good harbinger for 1997 at the time. Autumn soil moisture is a very important factor affecting the flood potential due to heavy clay soils (gumbo) which are relatively impermeable when wet. However, weather patterns changed following mid September, 1996. Significant rains on September 27, October 17-18, October 25-26 and October 28-30 greatly increased soil moisture, setting the stage for another possible flood.

Soil moisture was measured by the airborne gamma technique (T.R. Carroll et al, 1992) in early November, 1996. It averaged 29 percent soil moisture by weight for the upper 20 cm of soil over the entire watershed in Canada and the United States, excluding the Assiniboine River. South of Grand Forks, this moisture level was the 3rd highest since 1979 when the U.S. National Weather Service began these surveys. From Grand Forks to Emerson it was the 7th highest. Surveys in the Manitoba portion began in 1994; the 1996 moisture level of 28.5 percent was higher than that of 1995 but below the 33.5 percent of late October, 1994.

Soil moisture modelled by the Winnipeg Climate Centre of Environment Canada with the assistance of Manitoba's Department of Agriculture showed soil moisture by volume generally in the 60% to 90% of capacity range, with some areas greater than 90%. Soil moisture is modelled to a depth of 120 centimetres.

In summary, the soil moisture at freeze-up in the autumn of 1996 was above average and in some areas well above average. It was much higher than for the 1979 flood. However, it was not extremely high as it has been in some other years.

Winter Conditions (November 1/96 - March 20/97)

The winter was unusually long and cold with snowcover developing in early November, 1996 and remaining until mid April, 1997. There were four blizzards producing heavy snow and blowing snow and resulting in closure of major highways. Snowfall was difficult to measure due to the strong winds and heavy drifting, likely resulting in significant underestimation of precipitation at many sites. Reported precipitation was well above average in November, December and January. Manitoba Water Resources has computed monthly averages of precipitation reports in the watershed since 1940 based on data provided by Environment Canada and The U.S. National Weather Service.

The recorded precipitation for the 1996-1997 season and the 1940-1996 averages are as follows:

	Nov.	Dec.	Jan.	Feb.	Mar.	Total
1996-97 Season	47	31	37	11	28	154
1940-96 Average	22	16	15	13	24	90

Weekly snowcover maps issued by Minnesota's Department of Natural Resources showed the snowcover at the 95th to 99th percentile over most of the watershed throughout the winter. Generally below average winter temperatures and high snowpack albedos combined to produce minimal losses from the snowpack.

Despite below average winter temperatures, soil frost depths were generally below average with many areas reporting virtually no frost. This can be attributed to heavy snowcover which began early in the winter.

An airborne gamma snow survey conducted February 6-12, 1997 further quantified the snowcover. The water content of the snow averaged 140 mm upstream of Fargo, 122 mm from Fargo to Grand Forks, 115 mm from Grand Forks to Emerson and 112 mm from Emerson to Winnipeg. The snow cover in the United States portion was the highest on record and in the Manitoba portion among the highest on record. This, together with the above average soil moistures, did not bode well for the Red River Valley. Spring weather would be critical.

Spring Weather (March 21 - June 23)

A two week period of very gradual melting began on March 21 and continued until April 4. Temperatures during this period ranged generally from -5° C to +5° C with some melting during the daytime and freezing at night. There was plenty of sunshine and dew points were low. From Grand Forks to Winnipeg much snow disappeared, probably more through sublimation than by melting. Field surveys in southern Manitoba showed that by early April snowcover in many areas had decreased to much less than 100 percent, and as low as 50 percent on western tributaries. There was little evidence of ponded water or runoff as melt water was soaking into the generally unfrozen soil. Thoughts turned to the 1956 situation when a record snowpack melted very slowly, resulting in minimal flooding. Manitoba's River Forecast Centre was on the verge of downgrading its flood forecast when at the beginning of April, weather forecasts in both Canada and the United States began to mention the possibility of a "Colorado Low". These words strike fear into hearts of Red River Valley inhabitants since history has proven that such disturbances produce the most vicious snowstorms in this region.

Weather forecasts proved to be very accurate as a full-blown Colorado Low developed and, in characteristic form, moved in a north-northeasterly path across eastern Minnesota into northwestern Ontario. The Red River Valley, situated just west of its path in the area of maximum overrunning and vertical motion took the brunt of the storm.

Winds of 80 kph reduced visibilities to zero, created huge drifts and brought transportation to a standstill for days. The movement of the low was quite slow due to its deepening as strong troughing aloft nearly caused the low to become a vertical cut-off low. The resultant long duration of precipitation was a key factor resulting in storm precipitation totals reaching as high as 90 mm. The trajectory of the low resulted in the entire Red River Watershed from the northeast tip of South Dakota to Lake Winnipeg receiving the heavy precipitation. An important feature of the storm was that it produced a lot of rain in the headwater area (upstream of Halstad) where runoff from winter snow was already more advanced. Freezing rain, ice pellets and snow predominated in the northern half of the U.S. portion while Manitoba received ice pellets followed by heavy snow. Cold weather followed the storm with temperatures as low as -20° C. Thawing did not resume until April 13, a week later.

A reasonable approximation of reported precipitation for the April storm is given on Figure 1. which shows total April precipitation. Precipitation for the remainder of the month was only about 5 mm in the U.S. portion and 5-10 mm in most Manitoba regions. Average reported precipitation for the basin was 67 mm compared to the normal of 40 mm. It is likely that the true precipitation for April was considerably greater than reported, perhaps as much as 90 mm on average. The difficulties of estimating snowfall under extreme winds have been well documented by Environment Canada (B.E Goodison, R.F Hopkinson}.

Precipitation following the early April blizzard up to the time of the crest of the Red River in early May was well below average.

Melt of the snowpack was not particularly rapid on the whole, although some rapid melting occcurred April 18-19 in the northern United States portion. In the Manitoba potion the snow melted gradually from April 13-25. The melt rate was much slower than in 1979 when a somewhat lesser snowpack melted entirely in three days.

Total Winter/Spring Precipitation

Total basin precipitation from the start of winter to near the crest of the Red River in early May (Nov.1/96-Apr 30/97) as reported totals 221 mm, much above the normal of 130 mm. A bar graph of total winter and effective spring precipitation for each year from 1950 onward is shown on Figure 2. It is likely that the true total for the 1996-97 season was considerably greater than 221 mm due to the fact that there were four major snowstorms with strong winds.

An airborne gamma snow survey was conducted April 10-12 following the storm. It showed that the net moisture input since early November, 1996 had risen to 150 to 170 mm at most Manitoba points. In the U.S. portion the net inputs were 100 to 150 mm. These are the highest values on record. The observed water contents, adjusted to values above 35 percent soil moisture by weight, are shown on Figure 3. The gross moisture input must have been considerably greater since sublimation losses would have been at least 25 mm and water soaking below the 20 cm soil depth is not recorded. The latter would have been substantial, especially in the portion of the watershed south of Halstad.

Runoff Conditions

Runoff was underway in the Fargo area prior to the April storm but had barely begun in the area from Grand Forks to Winnipeg. This type of situation favours strong growth in the peak discharge as it moves northward. Simultaneous melt and runoff throughout the watershed, which has often occurred in past years, results in northern tributaries having long spent their fury when mainstem crests arrive from the south. In such cases the peak grows little and may even decrease as it moves northward. Growth of the peak flow in 1997 was further favoured by the April storm which produced rain in the south and snow in the north. The rain quickened runoff in the south but the high albedo of heavy snow in the north retarded melting. As a consequence peak flows from two main source areas in the United States, the southern portion upstream of Halstad and the Red Lake River, arrived at Grand Forks simultaneously. The peak continued to grow somewhat from Grand Forks to Winnipeg because northern tributaries were still running high when the mainstem peak arrived.

The spring runoff volume for the Red River at Emerson up to June 15 was 6.75 million acre-feet (8.33 million cubic dekameters), representing an average runoff depth of 135 mm. This is almost identical to the 1950 runoff volume. Yet the 1997 peak discharge at Emerson was about 130,000 cubic feet per second compared to that of 94,000 cfs in 1950. The peak at the Floodway Inlet just south of Winnipeg was 138,000 cfs compared to that of 94,000 in 1950. The higher 1997 peaks resulted mainly from the unfavourable timing effects described above.

The 1997 spring runoff was particularly heavy in the headwater area upstream of `Halstad, in the lower Pembina River Watershed and on most eastern tributaries of the Red River in Manitoba. Many streams in these areas recorded record or near record high flows. Flows on western tributaries in Manitoba were high but well below those of 1974 and 1979.

The 1997 spring runoff could have been considerable greater had it not been for the snowpack losses prior to the April blizzard and the four weeks of dry weather following the blizzard. Additional precipitation would have had a very high runoff coefficient due to the saturated and flooded fields. An 1826 flood magnitude could have developed with the occurrence of one additional major storm or several moderate storms.

Flood Conditions

The Red River reached above bankfull levels about April 20 and receded back within its banks in late May. Crest elevations 37 to 40 feet above winter levels occurred from late April to early May. The "Red Sea" inundated 1836 km^2 compared to 1000 km^2 in 1979. The flooded area between Emerson and Winnipeg for the 1979 flood is shown on Figure 4. About 28,000 Manitobans were evacuated to ensure their safety. Some 2000 cattle and 45,000 hens were moved out of the Valley. Ring dikes protected eight valley towns but one town and a hamlet, which had no permanent dike, were flooded. The City of Winnipeg was protected by major flood control works constructed in the late 1960's; only two dozen homes were flooded. Canada's military deployed 8600 soldiers, the largest peace-time deployment to assist with emergency flood fighting. About 756,000 m^3 of earth and 142,000 tons of limestone were used to construct the Z-dike, an extension of the west dike of the Red River Floodway Control Structure. The dike would normally take four months to build but was finished in one week. Total flood damages for the 1997 flood may reach $200 million compared to over $600 million (present value) for the 1950 flood. Damages prevented by flood control works and emergency diking in 1997 are in excess of three billion dollars for a 1957 level of development. Damages prevented for the 1997 level of development are not well known but could be two to three times greater.

Flood Forecasting Methodologies

Manitoba's River Forecast Centre employs an index type of model to predict the runoff volume and peak discharge for the Red River at Emerson. This is used in the preparation of flood outlooks which are issued during the winter and early spring. Once spring runoff is well underway, Manitoba depends on U.S. National Weather Service predictions for the Red River at Pembina, North Dakota located just south of the International Boundary.

The index model used for runoff outlooks consists of statistical relationships for the U.S. portion of the watershed, treating the entire area as one basin for computational purposes. Autumn soil moisture is represented by an Antecedent Precipitation Index (API) based on weighted monthly precipitation from May to October. The appropriate monthly weights have been carefully selected based on analysis of data from 1941 onward. Other variables used are the cumulative winter precipitation which includes effective spring precipitation, and a degree-day type of melt index. Also a winter temperature index is used to approximate sublimation losses and soil temperatures. Information from airborne gamma snow surveys, conventional snow surveys, satellite microwave snow surveys, modelled soil moisture, airborne gamma soil surveys and measured soil temperatures etc. has been increasingly used in recent years to improve estimates of soil and snowpack conditions.

Flood routings are performed using the Muskingum method from Emerson to

Winnipeg. For both outlooks and operational forecasts, daily predicted flows at Emerson are routed together with daily predicted flows for 13 Manitoba tributaries including the Assiniboine River. The Muskingum procedure performed very well for the 1997 flood. However, it does not enable predictions of flood levels on the floodplain well away from the river.

While present forecasting procedures worked well for the 1997 flood, the River Forecast Centre plans to update flow forecasting procedures to make them more physically based. This may include application of a dynamic routing model to the Red River.

Flood Forecasts for 1997

Forecasts of Red River 1997 crest elevations were issued by Manitoba's River Forecast Centre from February through the spring. These forecasts were quite accurate considering information on watershed conditions at the time the forecasts were issued.

Observed crest elevations from Emerson to Morris were within the range predicted on April 9, 1997 just after the major blizzard. At Ste. Agathe and St. Adolphe the actual crest was equal to the top of the range given in the April 9 forecast. Crests above and below the Floodway Inlet were 1.7 feet and 1.5 feet higher than the top of the range on the April 9 forecast. In downtown Winnipeg the crest was 0.2 feet above the top of the forecast range.

The increase in level forecasts on April 9 after the blizzard was not very great due to favourable weather during the two weeks prior to the blizzard, which had greatly depleted snowcover with little evidence of runoff or ponding. The April 9 forecast was issued based on an assessment of the flood potential by Manitoba's River Forecast Centre soon after the early April blizzard which produced heavy precipitation throughout the watershed.

Forecast crest elevations were revised upward April 18th and 20th when it became apparent that the crest at Grand Forks and Drayton would be higher than earlier predicted by the U.S. National Weather Service. The volume forecast was also increased significantly at this time.

Late in April, crest forecasts for points from Ste. Agathe northward were revised upward somewhat when it became apparent that high crests on many Manitoba tributaries would occur at virtually the same time that peak flows arrived from the United States.

Crest forecasts issued in February and March, 1997 and subsequent forecasts updates are shown on Table 1 together with the main reasons for the forecast revisions.

Red River Flood Statistics

1. Red River at Emerson	
1997 Peak Discharge	132,000 cfs
1996 Peak Discharge	72,000 cfs
1979 Peak Discharge	92,500 cfs
1950 Peak Discharge	94,000 cfs
2. Red River in Downtown Winnipeg	
1997 Peak Discharge	162,000 cfs (natural)
1997 Peak Discharge	80,000 cfs (actual)
1996 Peak Discharge	108,000 cfs (natural)
1996 Peak Discharge	58,000 cfs (actual)
1979 Peak Discharge	107,000 cfs (natural)
1979 Peak Discharge	55,200 cfs (actual)
1966 Peak Discharge	88,500 cfs (actual)
1950 Peak Discharge	108,000 cfs (actual)
1826 Peak Discharge	225,000 cfs (actual)
3. Red River at Morris	
1997 Peak Stage	783.3 feet
1996 Peak Stage	779.5 feet
1979 Peak Stage	781.3 feet
1966 Peak Stage	778.9 feet
1950 Peak Stage	781.7 feet
4. Red River Above Floodway Inlet	
1997 Peak Stage	771.3 feet
1996 Peak Stage	764.6 feet
1979 Peak Stage	765.0 feet
1966 Peak Stage	763.0 feet
1950 Peak Stage	766.0 feet
5. Red River in Downtown Winnipeg	
1997 Peak Stage	761.9 feet (natural)
1997 Peak Stage	752.1 feet (actual)
1996 Peak Stage	757.9 feet (natural)
1996 Peak Stage	747.0 feet (actual)
1979 Peak Stage	757.7 feet (natural)
1979 Peak Stage	746.8 feet (actual)
1966 Peak Stage	752.1 feet (actual)
1950 Peak Stage	757.1 feet (actual)
1826 Peak Stage	764.1 feet (actual)

Note: "natural" refers to what would have occurred without the use major flood control works such as the Red River Floodway, the Assiniboine River Diversion, and the Shellmouth Reservoir

FIGURE 1

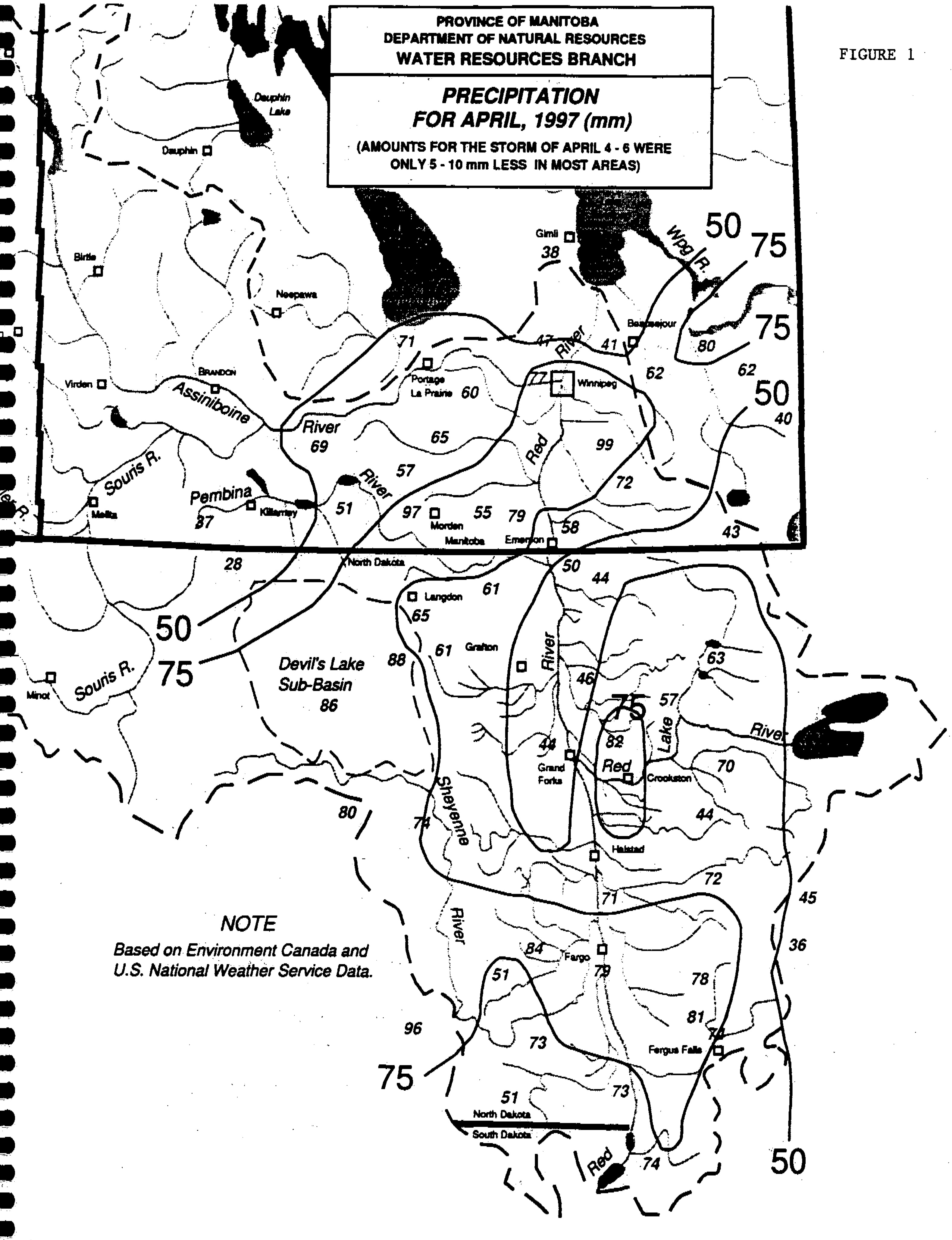

PROVINCE OF MANITOBA
DEPARTMENT OF NATURAL RESOURCES
WATER RESOURCES BRANCH
PRECIPITATION
FOR APRIL, 1997 (mm)
(AMOUNTS FOR THE STORM OF APRIL 4 - 6 WERE
ONLY 5 - 10 mm LESS IN MOST AREAS)
Dauphin Lake
Dauphin
Birtle
Neepawa
Gimli
38
Wpg R.
50
75
Beausejour
41
47
River
71
Portage La Prairie
60
77
Winnipeg
62
80
75
62
50
40
Virden
Brandon
Assiniboine
River
69
65
Red
99
72
Souris R.
57
River
Pembina
Melita
Killarney
37
51
97
Morden
55
79
58
Manitoba
Emerson
43
28
North Dakota
50
44
Langdon
61
65
50
75
Devil's Lake
Sub-Basin
86
88
61
Grafton
River
46
63
75
57
82
Lake
River
Minot
Souris R.
44
Grand Forks
Red
Crookston
70
80
Sheyenne
74
44
Halstad
72
71
45
NOTE
Based on Environment Canada and
U.S. National Weather Service Data.
River
84
Fargo
79
36
51
78
81
96
73
74
Fergus Falls
75
51
73
North Dakota
South Dakota
Red
74
50

FIGURE 2

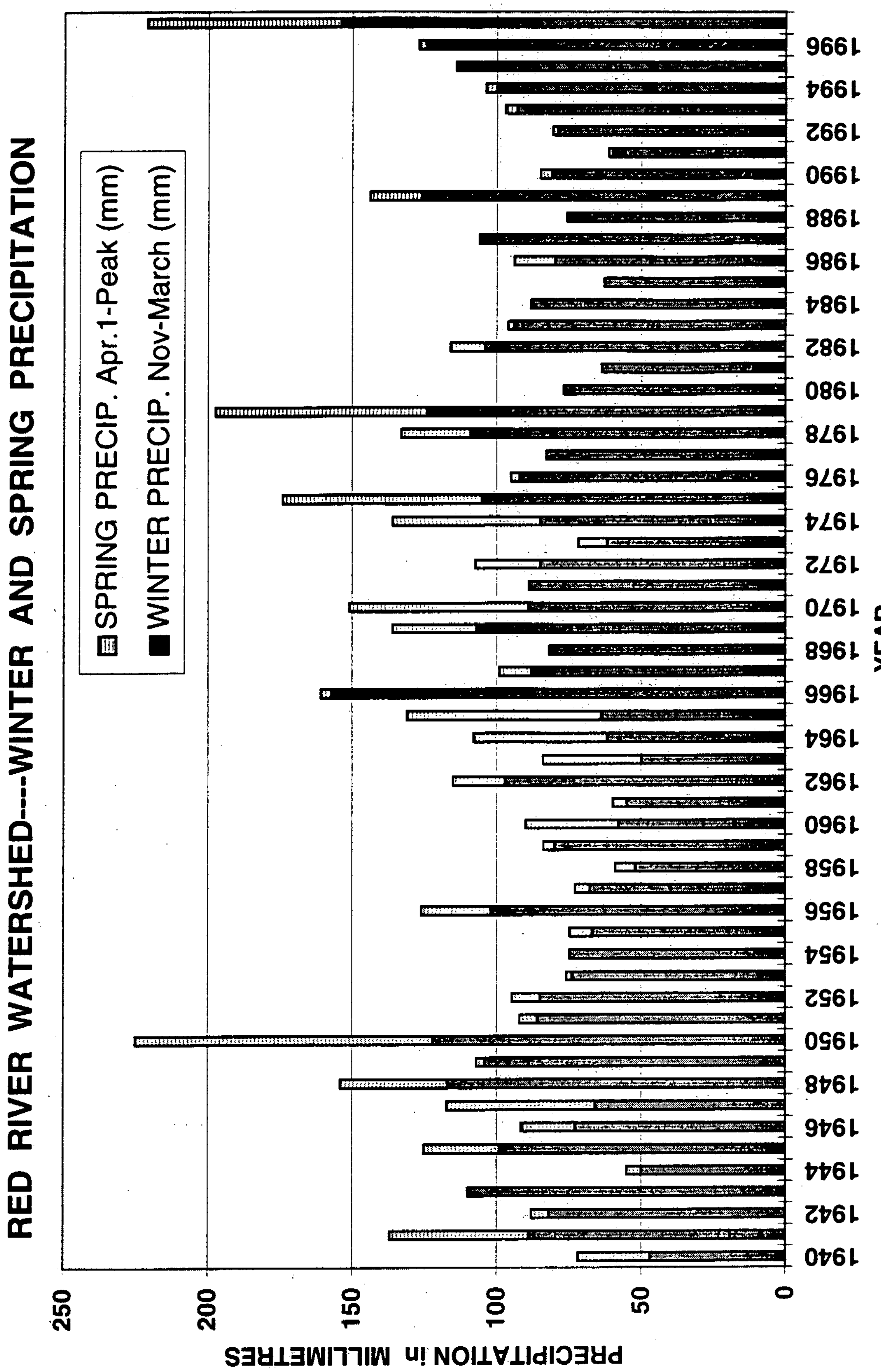
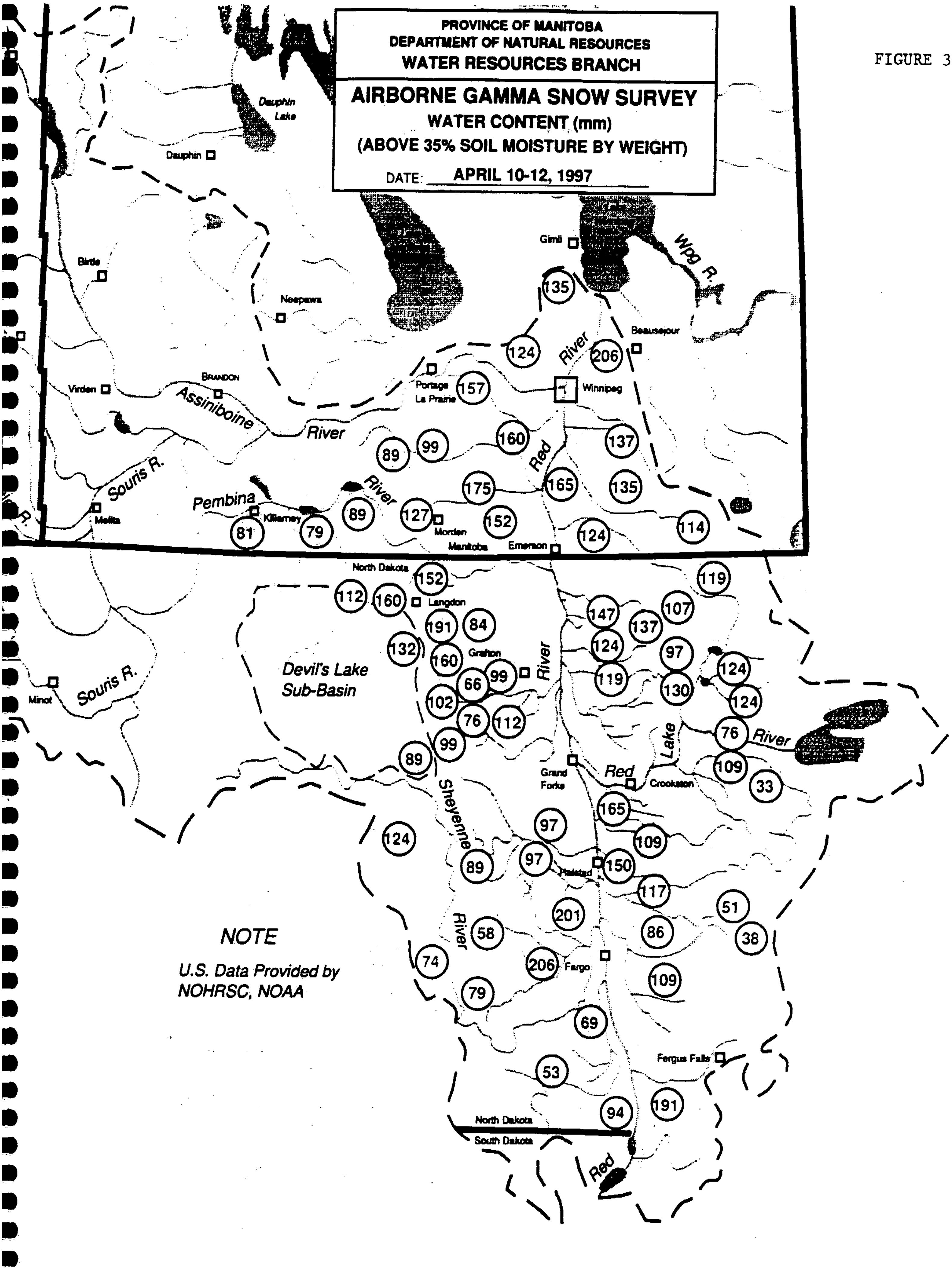

RED RIVER WATERSHED----WINTER AND SPRING PRECIPITATION
SPRING PRECIP. Apr.1-Peak (mm)
WINTER PRECIP. Nov-March (mm)
PRECIPITATION in MILLIMETRES
YEAR
0
50
100
150
200
250
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996

FIGURE 3



PROVINCE OF MANITOBA
DEPARTMENT OF NATURAL RESOURCES
WATER RESOURCES BRANCH
AIRBORNE GAMMA SNOW SURVEY
WATER CONTENT (mm)
(ABOVE 35% SOIL MOISTURE BY WEIGHT)
DATE: APRIL 10-12, 1997
Dauphin Lake
Dauphin
Birtle
Neepawa
Gimli
Wpg R.
Beausejour
Brandon
Virden
Assiniboine
River
Portage La Prairie
Winnipeg
Red
River
Souris R.
Pembina
Melita
Killarney
Morden
Manitoba
Emerson
North Dakota
Langdon
Grafton
Devil's Lake Sub-Basin
Minot
Souris R.
Grand Forks
Crookston
Red
Lake
River
Sheyenne
River
Halstad
Fargo
Fergus Falls
North Dakota
South Dakota
Red
NOTE
U.S. Data Provided by NOHRSC, NOAA
135
124
206
157
137
160
99
89
165
135
175
152
127
89
79
81
124
114
152
119
112
160
191
84
147
137
107
132
160
124
97
66
99
119
130
124
102
76
112
124
76
99
89
109
33
165
97
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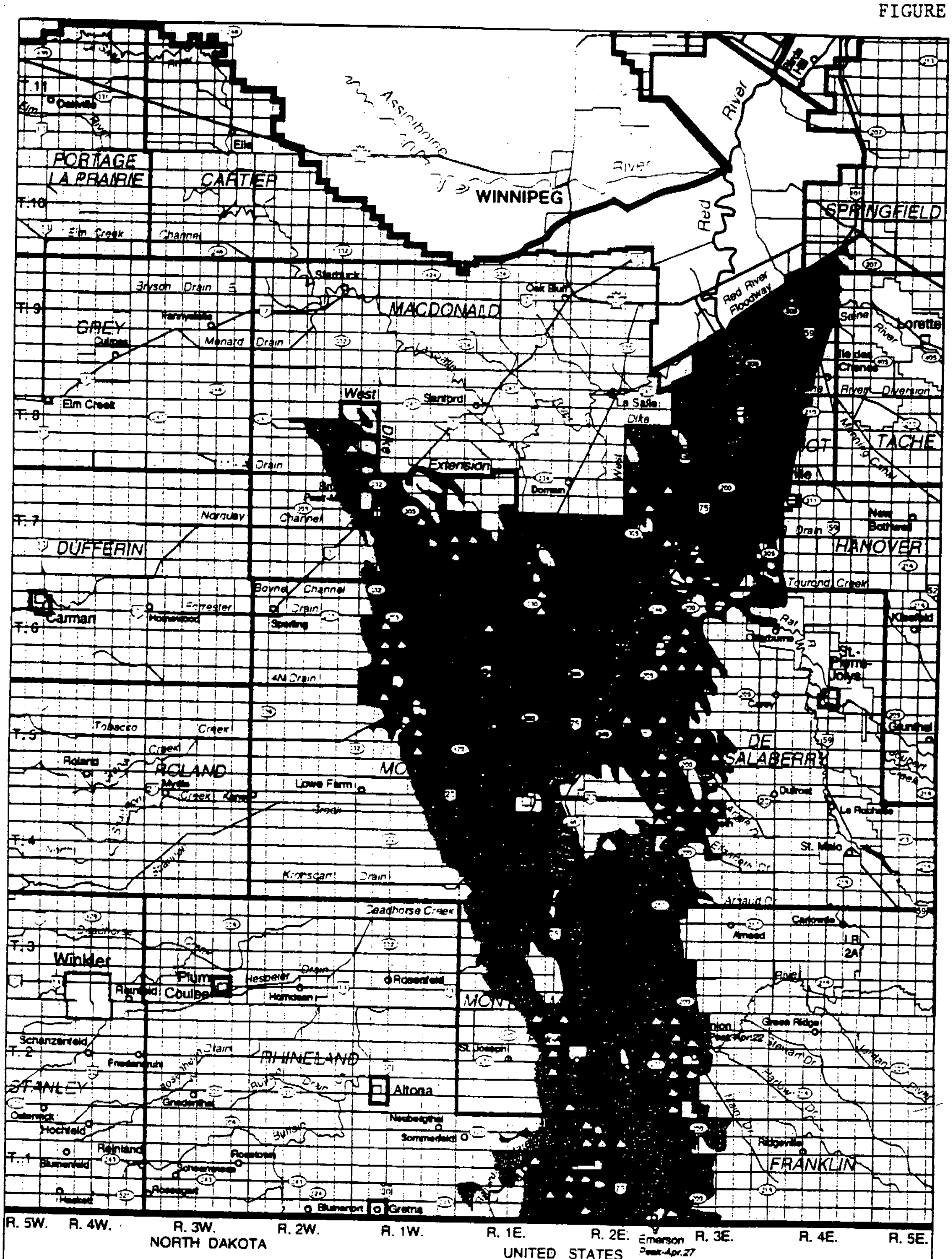
79
69
53
191
94



RED RIVER VALLEY

RED RIVER MAXIMUM FLOODED AREA FOR 1997

Based on Radarsat Imagery from April 27, May 1, May 4 & May 8 1997, and on aerial photography from April 29, May 1 and May 2, 1997.

Islands one or more this section (2 Ac.- 30 Ac.).

Road

Road Flooded

June 9, 1997

Manitoba Natural Resources

TABLE 1

Manitoba Water Resources Branch
River Forecast Centre

REVIEW OF RED RIVER CREST FORECASTING SPRING OF 1997

Predicted Crest Elevations In Feet						
Forecast Date	Emerson	Morris	Ste. Agathe	Floodway Inlet	Winnipeg (James Ave.)	Selkirk (PTH #4)
February 24	790.5-793.0	780.5-783.5	773.0-775.5	765.8-769.2	19.3-22.5	
March 21	791.0-793.0	781.0-783.5	773.0-775.5	765.2-769.0	19.3-22.3	
Favourable Melt Followed by April 4-6 Blizzard						
April 10	792.0-793.5	782.0--784.0	774.5-776.0	767.3-769.6	19.7-24.3	725.0-727.5
River Levels at Grand Forks rise much higher than predicted						
April 18	793.0-793.5	783.0-784.0	775.5-776.5	768.3-769.5	20.4-24.3	725.0
Crest Levels at Grand Forks revised upward significantly						
April 20	794.0-795.0	784.5-785.5	776.5-777.5	769.0-770.0	23.5-24.5	726.5-727.5
Manitoba Tributaries crests coincident with Emerson Crest						
April 27	Near Peak	784.5-785.5	777.0-778.0	769.5-770.5	24.0-25.0	727.0-728.0
Update Based On Flow Measurements at Ste. Agathe						
April 29	Crested	Near Peak	776.5	770.0-770.5	24.0-25.0	727.0-728.0
Observed Conditions						
Actual Crest	792.5	783.0	776.5	771.3	24.5	726.2
Crest Date	April 27	April 30	May 2	May 4	May 2-4	May 4-5
Total Rise (ft.)	40.3	39.8	37.0	38.3	24.0	N/A

THE CITY OF WINNIPEG
FLOOD PLANNING, PREPARATIONS AND OPERATIONS

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Introduction

The City actively planned, prepared for and undertook specific flood protection activities as necessary in response to high river levels and overland flooding this past spring. Most City Departments and over 2,500 staff were involved in the activities this year, however, the focus of this paper is primarily the activities carried out by the Water & Waste and the Streets & Transportation Departments. The presenters would like to acknowledge the many individuals in the two departments for their contributions to this paper.

Red River and Assiniboine River Monitoring and Forecasts

An initial long range outlook for spring flooding was issued by Manitoba Water Resources Branch, and immediately distributed on February 26th, 1997. Once rapid increases in river elevations had commenced on April 6th, monitoring of river conditions continued until levels dropped below 7.0 feet at James Avenue on June 17th. Ongoing communication with the Manitoba Water Resources Branch and Environment Canada enabled daily updates of short term forecasts and long range outlooks for expected weather and river conditions. Daily river forecasts were issued between April 10th and June 4th. The City set up a river elevation information (phone) mail box which was updated twice daily during extreme elevations, and once daily under less threatening conditions.

In addition to the ongoing dialogue with Manitoba Water Resources Branch and Environment Canada, the City commissioned UMA Engineering Ltd. to collect water level data on a daily basis over various reaches along the Red and Assiniboine Rivers, and along some tributaries during high flow conditions. This data would provide warning of potential trouble zones within the river system, and would prove to be valuable in future flood control and planning exercises. Monitoring of river ice conditions was undertaken in cooperation with the Winnipeg Amateur Radio Emergency Service and the Winnipeg Police Service. This program was established in order to provide warning of potential ice jam conditions, and to identify ice jams which could result in short term sudden rises in water levels over various reaches of the river system.

Flood Protection for High River Levels

The Primary Line of Defence (PLD)

With the Manitoba Water Resources Branch April 19th flood forecast it was apparent that the City of Winnipeg's Primary Line of Defence (primary dykes) would have some deficiencies for levels in the higher range of the forecast. Flood levels would be close to 24.5 feet at James Avenue, the City's datum, which is 727.57 feet above sea level. It was decided that the primary dyke system, where deficient, should be built to 26.5 feet at James Avenue, the forecasted river elevation plus two feet for freeboard.

The Water and Waste Department began a review to determine the Primary Line of Defence deficiencies. Initially, deficiencies were identified by using existing PLD drawings and plotting the projected river elevations. In some cases the PLD drawings were not up to date and surveyors were sent out to determine ground profiles. Staff were also sent out to inspect the total length of the City's primary dyke system, to confirm deficiencies identified on drawings and to look for unknown deficiencies or "holes". Each inspector inspected a portion of the dyke, identifying low spots or culverts that go through the dyke. There were 26 locations of culverts identified as breaches, most of which were plugged by the Local Water and Sewer Division.

There were 20 locations where the PLD had to be raised; these ranged from small clay dykes several feet in length and height, to dykes built on streets that extended several blocks and were 5 to 10 feet in height. The earth dykes were "keyed" or excavated into the existing ground to prevent failure or leakage of the dyke.

The Secondary Line of Defence

The secondary line of defence or secondary dykes are those dykes that are not designated as primary dykes in the Provincial Statutes. Typically, secondary dykes are permanent and constructed of earth fill or temporary and constructed of sandbags or earthfill or a combination of both. Secondary dykes are usually located on private property, which property is typically situated outside the protection of the primary dyke system.

For flood planning, lists of properties at risk were generated for the forecast peak flood water levels. Although early forecasts by the Province in February and March typically include median and upper decile forecasts, the City adopted policy is to plan and prepare for the "worst case" or the upper decile forecast. The estimated sandbag requirements are based on constructing secondary dykes to a level two feet above the forecast water level.

An information package was provided to all property owners who were identified as requiring a secondary dyke. This package included information on the dyke height, alignment, dyke design and building, dyke policies, volunteers., etc. Three hands-on sandbag dyke building demonstrations/public information meetings were held, one in St. Norbert, one in West Kildonan and one in central St. Vital.

Sandbag requirements for properties at risk were summarized in spreadsheets. These spreadsheets were updated daily in the beginning and hourly closer to the flood peak, as survey information was received from the field. The spreadsheets package was distributed daily to a key list of staff involved in sandbag production and delivery, including the Flood Call Centre.

Surveys were undertaken on all properties at risk plus many more. In mid-March, survey crews were out placing permanent elevation markers on the buildings (houses) on known properties at risk. Approximately 100 buildings were tagged before survey crews moved to higher priority surveys for flood preparations. These markers allowed the City staff to respond more quickly and accurately to the constantly changing river forecast elevations when setting or re-setting dyke elevations. Surveys were also undertaken to determine the status of properties where there was no information and to set line and grade for the secondary dykes.

All secondary dykes were inspected regularly during construction. Initially the dyke inspection was undertaken by Water & Waste Department and Streets & Transportation Department staff. As the flood evolved, however, there was a greater need for more staff to be involved in inspection but also all other aspects of the dykes. Sometime before the flood peak, there were teams of two people walking and monitoring and inspecting the dykes all across the City on a 24 hour basis.

The Streets and Transportation Department set up the Dyke Operations Centre (DOC) at 1155 Pacific Avenue. The initial objectives of the DOC were to coordinate all surveys and manage the survey records and forward same to the sandbag delivery coordinators. As the flood evolved, phone lines were set up at the DOC to handle the numerous public requests for surveys and to answer any other technical questions on flood preparations. The DOC also coordinated the "dyke watchers", assisted in coordinating the evacuations and repatriation, and assisted in coordinating dyke breach repairs with GERT (see below), the Armed Forces and the City's Construction Branch.

Approximately 800 properties in the City of Winnipeg were protected by secondary dykes. This included 52 properties above (south) of the Floodway. It also included 50 properties on the inside of Kingston Crescent that did not actually receive sandbags but were protected by those properties that did. In total, it was estimated that 3,900,000 sandbags were required to protect the 800 properties. However, total sandbag production was 6,608,000 sandbags, of which 4,338,000 sandbags were produced by the City's sandbagger machines and 2,270,000 sandbags were hand filled by volunteers, the penitentiary, the Armed Forces, etc.

The large discrepancy between estimated and actual sandbag requirements is due to several factors. Dyke construction by hundreds of volunteers, most of whom did not get dyke building training, did not follow the standard dyke design as promoted by the City. Most dykes were more "fortified", ie they were constructed much wider and higher than designed, requiring more sandbags. Even with regular construction inspection by City staff, property owners and volunteers either disagreed or ignored the advice on dyke construction.

A tremendous number of sandbags were required at many miscellaneous locations for many reasons. Dykes were shored up with additional sandbags to prevent leaks and failures. Sandbags were required at many locations for repairing dyke leaks and failures. One example of this is when a drainage pipe through a permanent dyke leaks and a smaller ring dyke is constructed around the inside end of the pipe to contain the leak. Many sandbags were required for sealing manholes from overland flooding, for dyking around existing permanent or temporary mobile pump stations, and for anchoring other flood protection works such as plywood splash boards.

Sandbag Dyke Removal

In mid-May, all residents who received sandbags were advised by letter that sandbag removal should be initiated. Of these, half the properties were advised that they were identified by the geotechnical engineers where removal of sandbags should begin immediately due to the potential for riverbank instability and failure. The City assisted property owners with the removal of sandbags by coordinating the Armed Forces, contractors and volunteers. The City had the bags picked up from the pavement of the front street and disposed of in the landfill or on private property with the permission of owners. Citizens were also allowed to remove sandbags from the piles on the streets for general yard and garden use. Sandbag removal was essentially complete by June 25th.

Geotechnical Emergency Response Team (GERT)

A working group of geotechnical engineers and specialists from the City of Winnipeg staff and from local engineering consultants was put in place to respond to the increasing needs for geotechnical expertise in the flood fight. The geotechnical consultants involved were UMA Engineering Ltd., KGS Consultants, Dyregrov and Associates and Agra Consultants. The greatest need came from the dyke inspection teams which provided 24 hour per day surveillance on the dykes. GERT inspected all sandbag and earth secondary and primary dykes, looking for potential dyke failures and breaches. When there was a failure GERT was consulted as to the method of repair. GERT was a 24-hour operation that was headquartered at 1155 Pacific Avenue.

GERT also evaluated riverbank stability where temporary dykes were built, and priorized the removal of those dykes to minimize riverbank failures. The drawdown of the Red River and the weight of temporary dykes were key factors in determining the stability considerations for dyke removal or permanence.

Several members of the GERT team were retained after the committee was disbanded to assist in conversion of some of the primary and secondary earth dykes to permanent structures.

Secondary Earth Dykes

In mid-April, a decision was made to protect some properties with earth secondary dykes rather than sandbags. This was based on the fact that with the then forecast, some properties would require 30,000 sandbags or more. Not only would these locations be faced with a tremendous labour effort, but the City's supply of sandbags was seriously going to be compromised and it was determined that earth dykes would be a better defence and more cost-effective. The criteria for earth dykes was: 1) property owner permission, where required; 2) sufficient lot size to permit use of heavy earth moving equipment, and potential for the dyke to remain after the flood. In total, 55 locations had secondary earth dykes, of which 45 were on private property.

Construction of Primary and Secondary Earth Dykes

The Water and Waste Department undertook the coordination of contractors, equipment, consulting services, construction control and the supply of suitable earth dyke materials required for the deficiencies in the Primary Line of Defense (primary dykes) and construction of secondary earth dikes.

Contractors affiliated with the Manitoba Heavy Construction Association were contacted to assess equipment requirements and construction methodologies on a dyke per dyke basis to ensure their suitability to perform the required works. To have the dykes in place within the required time frame, a 24-hour operation was provided at many of the sites by several of the contractors. Payment for equipment was made on an hourly basis.

Cartage of dyke materials during the construction phase was arranged by the Streets and Transportation Department. The cartage was also a 24-hour operation and payment was at the hourly rates. The magnitude of the operation required that over three hundred units (tandems or trailers) were required for several days prior to the arrival of the flood peak.

Geotechnical engineering consulting services from UMA Engineering and KGS Consultants were engaged to assess impacts to riverbank and dyke stability, to identify and address permanency considerations including permits and to provide construction control for the larger dykes, such as Turnbull Drive, Wildewood Club and St. John's Ravenscourt .

The supply of materials for dyke construction necessitated creating borrow areas at the Brady Road Landfill Site, St. Mary's Road and Courchaine Road, Turnbull Drive at the Floodway Berm and King's Park on King's Drive. The Turnbull Drive and King's Park borrow areas provided on-site dyke material required for a "cat and scaper" method of construction. The borrow areas at Brady Road and St. Mary's Road supplied materials that were transported by trucks to the various dyke sites. An estimated 300,000 cubic metres of clay material was removed from the Brady Road site during the dyke construction phase. The borrow area at Brady Road was located where the next below-grade refuse cell was to be constructed. The borrow areas at Turnbull Drive and St. Mary's Road were restored by seeding and regrading to provide positive drainage.

In total, earth dykes were constructed at 80 locations throughout the City (25 primary dykes and 55 secondary dykes).

Conversion of Primary and Secondary Earth Dykes

The dykes at 50 locations (10 primary dykes and 40 secondary dykes) were modified to become permanent structures. Some notable locations of raised primary dykes that remained include behind St. Boniface Hospital, the end of Whellams Lane in North Kildonan, and on Salme Drive in St. Vital.

The majority of the secondary dykes were on private property and any conversion plan had to be agreed to by the property owner. The final height and the location of the dykes were largely dependant on bank stability, level of flood protection the owner desired, ability to maintain the dyke (grass cutting), and aesthetics (ie. view of the river and impact on trees, fences, and decks, etc.). Some notable locations where temporary secondary dykes were made permanent are Turnbull Drive, Parkwood Place, Rue Des Trappiste and several ring dyke locations south of the Floodway.

Restoration of converted secondary dykes was the responsibility of the property owner. Dykes that remained and would be designated as portions of the Primary Line Defence were restored and sodded.

Brunkild "Z-Dyke" and St. Norbert Protection Dyke

On April 24th, the City became aware that the provincial authorities were concerned that the length of the West Dyke was insufficient to prevent expected flood waters from spilling into the La Salle River and flooding the City from the west, and they had in fact begun construction of a 24 kilometre extension on April 23rd. This was to be further extended some 16 kilometres as construction proceeded.

Due to rising floodwaters, the ambitious schedule was to complete the 24 kilometre, 5 - 8 foot high dyke in 5 days, by April 28th, the date that flood waters were expected to attain the dyke. The Manitoba Department of Highways directed the project with assistance from a large private contractor and the Armed Forces. This was done under less than ideal soil/weather conditions and materials, with no freeboard allowance.

Acres Consulting Engineers (retained by the City) completed a computer simulated "dyke-break analysis", ultimately indicating that a breach in the Z-Dyke could result in a worst case 60,000 cubic feet per second (cfs) discharge, flooding Sanford, LaSalle, and St. Norbert north to PTH 100. The Manitoba Water Resources Branch (MWRB) further advised that portions of the existing West Dyke also had to be raised. Serious concerns were raised about the integrity of the raised dyke, considering the lack of freeboard and construction practices, steep side slopes, wind, wave, debris, erosion, and rain potential. Due to these concerns, the following were immediately undertaken:

- The City and the Province agreed to assess/coordinate a 24 hour evacuation notice for the R.M. of MacDonald and St. Norbert when flood waters attained the base of the dyke.

- The City revised it's planning strategy in terms of "The Real Event", which was the forecasted flood event, and "The Potential Event", a breach of the Z-Dyke, in order to allocate resources.

- The City established the South Perimeter Highway (PTH 100) as a Primary Line of Defence (PLD), as a more secure and defensible structure to protect the city at large in the event of a breach.

- The City constructed the St. Norbert Protection Dyke along the southern limits of St. Norbert north of the La Salle River. This dyke ran from the raised primary dyke on the east side of Pembina Highway over to the west side along Rue des Trappistes to the Brady Road landfill.
- At a Manitoba Emergency Management Organization (MEMO) meeting, it was decided that the Armed Forces, the Province, and the City would join forces in an intensive 2-day evaluation and mass evacuation planning session at Building 84, CFB Whytewold on April 29th. Several key staff representing all major Provincial and City departments participated, including fire, police, health, and social services. At stake was the potential evacuation of 125,000 city residents.

- Under direction of the MWRB, a "Z-Dyke Engineering Task Team" was set up to determine critical hydraulic/hydrology parameters and level forecasts, provide technical advice and information to other agencies, and develop contingency floodway operations scenarios. The ten member team consisted of hydraulic engineering experts and hydrologists from the MWRB, Acres Consultants, University of Manitoba, Manitoba Hydro, and the City. The first meeting was held on April 29th, and the team met approximately daily for the following two weeks. As a result of dealing with other issues, this team was later renamed the "Flood Management Task Force".

On April 28th, the initial 24 kilometre phase of the Z-Dyke was completed on schedule. The 16 kilometre extension and improvements to protect the Z-Dyke were initiated.

At the CFB Whytewold sessions, it was determined that evacuations would be required only south of PTH 100 (St. Norbert) and possibly in low unprotected areas within the City involving up to 10,000 residents in total. Operations plans were produced to effect this.

The Z-Dyke Engineering Task Team determined that under the worst case scenario (60,000 cfs breach), flow estimates were 88,000 cfs in the floodway channel (60,000 cfs is design capacity, but the channel has some "reserve capacity") and 92,000 to 100,000 cfs in the City (1950 was 108,000 cfs). Some 8 major openings in the floodway banks were identified for closure. They determined that it was theoretically possible to store floodwaters for 5 to 8 days and thereby maintain control of the floodway. This meant holding the level at 24.5 feet at James Avenue, although levels would be relatively higher in south Ft.-Garry/St. Vital/St. Norbert (761.5 vs. 760.0 feet), and the PLD would have to be raised 2 feet in selected areas south of PTH 100. This plan made it possible to protect the City from a Z-Dyke breach scenario.

Fortunately, a decision on implementing this plan was ultimately not required due to a series of fortuitous events. A land ridge paralleling the Morris River formed a natural barrier impeding flood waters. Favorable (north) wind conditions, combined with the elevated rural mile-road network, slowed the northward pace of floodwaters. Very little rain fell and drying conditions were favorable. Flood levels at Brunkild did not follow those at Morris as expected, and were much lower. By May 5th, it was evident that the risk of any breach had fallen considerably, and only a strong south wind combined with significant rain could pose a threat, an unlikely, although possible event. The risk diminished daily, and the City's EOC decided to repatriate the St. Norbert evacuees starting May 12th, subject to removal of major dykes and stabilizing the sewer system.

Overland Flooding

Several activities were undertaken to reduce the chance of overland flooding in South Transcona and Charleswood. Snow and debris were removed from the local ditches and frozen culverts were thawed. In fact, snow had to be removed a second time after the blizzard on April 5th to 8th, but there were only sufficient resources available to clean the major ditches and drains. Sandbags were made available at Streets maintenance yards for pickup by the general public, and also at the Esso gas station in South Transcona.

Other flood protection measures undertaken in South Transcona included the setup of a temporary mobile pump to transfer water from the Dugald Ditch to the wastewater interceptor in Dugald Road. As well, a temporary pipe interconnection between the Dugald Ditch and the land drainage sewer system in Regent Avenue was opened to divert part of the flow from the Dugald Ditch. Together, these temporary short term measures canot handle the spring runoff, as proven again this year with flooding resulting.

As a result of high flows in Sturgeon Creek, water spilled over the Ness Avenue and it was closed to traffic for approximately one week in late April. The Saskastchewan Avenue road crossing was also closed for the same time period. Water did not spill over the road but was lapping at the edge and did cause some erosion at the road and also at the railway crossing.

In several locations throughout the City, watercourses had well above normal water levels, as a result of snowmelt runoff and reduced outlet capacity, but overland flooding was prevented. For example, Baldry Creek and Beauselais Coulee were plugged at the outlet to prevent back up of the Red River and temporary pumps were setup to dischrage the accumulated runoff. As well, the Lot 16 Drain gate at the outlet was closed also to prevent the back up of the Red River and a temporary pump was setup.

Bunn's Creek had a flow of approximately 200 cubic feet per second during the peak of the Red River. It was determined that it was not feasible to block Bunn's Creek at the outlet to the Red River and set up temporary pumps. To prevent overland flooding due to Bunn's Creek flows and back up of the Red River, earth and sandbag secondary dykes were constructed and manholes on the land drainage sewer system were sealed.

Truro Creek was not a problem this year as the City and the Winnipeg Airports Authority Inc. met prior to snowmelt runoff and devised a plan to prevent overland flooding. The preventative actions were carried out by the airport staff on airport property.

Pumping Station and Gate Operations

In preparation of the forecast peak water level, wastewater collection crews undertook an extensive system wide check of flood pumping stations and gates to ensure that all facilities were operational and that their operating status was appropriate. Initial flood preparation activities also included the issuing of electrical inspection requests to Manitoba Hydro, Winnipeg Hydro, and the Water and Waste Electrical and Instrumentation Branch, in order to ensure a satisfactory degree of flood readiness existed within the sewer collection system. A request to Winnipeg Hydro to upgrade the feeder priority of each of the Flood Pumping Station services within its service area was also made.

Commencing April 7th, the Water and Waste Department Regional Operations Division and Local Water and Sewer Division undertook flood activities in accordance with the Flood Activity Manual. This manual includes most activities related to flood proofing the sewer systems on the major rivers, and is revised annually in accordance with changes in the collection system. Specific activities are related to rising river levels, and include activation and operation of the flood and underpass pumping stations, and checking or operating flap and positive control gates on the sewer systems. During the 1997 spring high river event, all of the City's 34 flood pumping stations were operated and a total of 131 flap and positive gates were checked and/or operated on the sewer systems.

Operational complications encountered included leakage through surge well stop logs and discharge blocks at some flood pumping stations. These problems, which had not been experienced by existing staff in the past, were a product of the exceptional high river levels being experienced at the time. High flow rates were also present throughout much of the sewer system as undocumented cross-connections, undetected leakage, and ungated outfalls all contributed additional water. A variety of measures were used to plug and control known sources of additional inflow.

Stormwater Retention Basin Monitoring

Stormwater Retention Basins (SRBs) were operated during the high runoff and high river flow events during the spring of 1997 to function as rainfall storage reservoirs for runoff within the city during high river levels. Additional pumping was established within SRB and other land drainage systems to provide the maximum runoff storage possible in the event of significant rainfall. UMA Engineering was hired to survey water levels of critical SRBs, particularly those with walkout basements. This information provided operational data and warning as to potential problem sites. Sandbagging of homes bordering on SRBs took place on three occasions with no flood damage resulting.

Isolation of Whyte Ridge SRBs and installation of an earthen dike for Waverley Heights' SRBs took place to protect against Lot 16 Drain. Baldry Creek and Beaujoulais Coulee were also isolated to prevent the Red River from backing up into the Fort Richmond SRBs. The Ravelston Deep Pond was pumped at Ravelston and again at Kildare and the Floodway to maintain a low level in both the Kildare trunk sewer and the Transcona land drainage system.

Temporary Pump Setups, Gate Closures and Plugging of Dyke Breaches

All land drainage, combined sewer and wastewater overflow outfalls penetrating the primary dykes that had either flap gates or flap and positive gates were checked for proper operation and were operated in accordance with the Flood Manual. A number of outfalls without control gates were identified before river levels reached elevations that would cause a concern for the systems they serviced. Temporary control devices such as inflatable bags or sand bags were installed, normally on the river end of the outfalls. Submerged breaches were plugged from the dry side.

Temporary pumping was installed at locations identified in the flood manual and at several other locations to pump any flows in these outfalls into the receiving streams. There are a small number of outfalls (both City and private) that penetrated dykes that were not gated. These outfalls and any interconnections between the wastewater, combined and storm sewers were plugged to prevent overland and basement flooding. Breaches of the primary dyke on Victoria Crescent caused by unknown and unauthorized septic field outlets caused some concerns. One breach was closed by filling a septic tank with concrete.

Isolation of Water and Sewer Service in St. Norbert

Contingency plans were developed to isolate watermains and sewer mains servicing St. Norbert should St. Norbert be flooded. Watermain valves would be closed to prevent contamination of the water supply north of the Perimeter Highway. Wastewater sewers would be plugged to prevent inundation of the waste water sewer system. Breaches of the Perimeter Highway and the temporary St. Norbert Protection Dyke (west) were identified at the outlet for the Baldry Lakes, Beaujelais Coulee and the Westendorf Coulee. Combinations of air bags, coffer dams and clay plugs were used to close these breaches. Very large electric submersible pumps and tractor driven agricultural pumps were installed and operated to reduce water levels in the Baldry lakes, Beaujelais Coulee and Westendorf Coulee. Installation of discharge piping for the Baldry Lakes system necessitated closure of the Perimeter Highway.

Sewer Modification in Homes, Apartment Blocks, Commercial Properties and Parks Buildings

Modifications to basement plumbing were required in a number of homes protected by sandbag and earth secondary dykes. If the secondary dykes would have failed, basements would have been flooded and river water would be able to enter the wastewater sewer system through floor drains, toilets, sinks and other plumbing fixtures. This would overload the wastewater system and would result in basement flooding in areas that were protected by the primary dykes. Modifications were made in a manner so the weeping tiles could continue to function. Up to 12 plumbers and 6 helpers made these modifications to approximately 500 homes. In addition there were a number of homes that had to have modifications made to main floor plumbing where the main floor was at an elevation lower than the forecast peak water level. In a few instances where secondary dykes did fail, divers were used to plug floor drains completely so weeping tile flows would not overwhelm the wastewater sewers.

Approximately 65 apartment blocks and commercial properties protected by secondary dykes were inspected and plumbing modifications, including temporary pumping, was done on approximately 50% of those properties. Any modifications were done at the owners cost, normally by plumbers engaged by the owners.

Parks facilities subject to flooding were inspected and Parks staff flood proofed any plumbing fixtures or breaches of primary or secondary dykes.

Sealing of Wastewater Manholes

The sealing program was conducted to ensure wastewater sewers were not overwhelmed due to street inundation during a rainstorm event. Several areas of the City in separate sewer districts were below the forecast peak river level. Separate sewer districts were actually more susceptible to flooding during the peak than most combined sewer districts, due to the lack of permanent pump facilities.

Sealing was performed by regrouting below the metal frame of the manhole, installing manhole lid plugs, double wrapping the cover with polyethylene sheet, replacing the manhole cover and placing sufficient sandbags to cover the frame and lid. At locations where inundation was almost certain, a rubber caulking or "Ram Neck" was applied to ensure sufficient sealing.

Between 200 and 300 wastewater sewer manholes located in low-lying areas were sealed during the flood. This included critical structures such as low lying gate chamber access structures. All manholes throughout the City on both the wet side and dry side of the primary dyke below James 25.0 feet were sealed. In addition, manholes lying below James 25.5 feet and James 26.0 feet was performed for manholes south of the Perimeter Highway and in the Baldry Creek catchment area, respectively. As well, manholes below elevation 232.2 feet geodetic in the Kildare Trunk (Transcona) area were sealed to provide protection to a 25 year spring storm.

Treatment Plant Operations

Flood water from high river levels, and to a lesser degree overland flooding, entered the wastewater and combined sewer systems and was conveyed to the wastewater treatment plants. These additional flows required additional pumping at the plants and hence additional electrical costs were incurred.

During peak river levels, reduced hydraulic capacity at the North End and South End Water Pollution Control Centres necessitated the shedding of hydraulic load in the south end of the city, and the bypassing of treatment plant processes in order to minimize head loss through the treatment plant facilities. Load shedding took place at D'Arcy, Cockburn, Baltimore, and Mager Sewage Pumping Stations. Diversion of Windsor Park Sewage Pumping Station flows to the North End Plant also took place. These activities were successful in avoiding an overloading of the interceptor system and wide spread basement flooding.

At the SEWPCC, Primary and Secondary treatment processes were bypassed. Diluted sewage was pumped to the river. At the NEWPCC, the sewage received primary, but not secondary treatment. This situation occured roughly over a 2.5 week period from May 24th, and was common to virtually all wastewater treatment plants along the Red River over peak river levels. The weakness of the wastewater, the low water tempreature, and the record high flows ensured that no environmental or public health consequence would result. Manitoba Environment was formally notified of this situation.

GWWD Railway/Water Supply

Regional water supply facilities experienced the following problems during the flood. The GWWD Railway which parallels the Shoal Lake Aqueduct, experienced washouts at 20 locations where local drainage ditches were unable to cope with the flood level run off water. Large quantities of ballast and a number of new culverts were installed at the wash out locations. The railway was out-of-service for a number of weeks which restricted access to the City's Water Intake at Shoal Lake. Fluoridation of the water supply was interrupted at the Intake due to a chemical shortage which lasted from May 9th to May 21st.

Deacon Booster Pumping Station was at risk of flooding. Ditch maintenance and a clay dyke successfully prevent any flooding at this location. A reservoir drainage pump building at Deacon Cell 1 experienced minor flooding. This location was protected by a sandbag dyke. In addition, a valve pit was dyked at Tache Booster Pumping Station as a precaution against flooding.

Elevations were checked for McPhillips, Hurst, and MacLean Water Pumping Stations and Reservoirs. The elevations at these facilities indicated that protection against flooding was not required.

Evacuation and Repatriation:

Under the authority of the Emergency Measures Act, the City evacuated specific properties for the safety of the public. The evacuations were undertaken on a area by area basis depending on risk and consequences of dyke failure. Specific criteria was established and areas were reviewed for evacuation as specific survey data was available and as the river levels rose. For example, the houses south of the Floodway and others with ring dykes were evacuated when vehicle access was no longer possible due to flood waters. Other areas protected by sandbag dykes were evacuated when the water level was one foot above the lowest sandbag level and/or when the water level was one foot below the house main floor.

Homeowners were given evacuation notices as much in advance as possible and such notices included a evacuation checklist of what to do in advance, what to do when evacuating and what to take with you. Where the evacuated houses were conected to the sewer system the City arranged to have plumbers plug all fixtures below the forecast peak water level.

In total, over 9,000 people were evacuated form their homes. Most were from the St.Norbert area as a precaution against the potential Z-Dyke failure. Other areas were south of the Floodway, Kingston Crescent and Scotia Street, to name a few. All the residents in between the Primary Dykes throughout the City where at one point put on "evacuation alert", when the City first learned of the potential Z-Dyke failure scenario. This was later rescinded when the Z-Dyke failure scenario flow potential was reduced.

Repatriation of the evacuated residents was even more of an effort than evacuation. Although the criteria was generally the reverse of the evacuation criteria, there were many other issues to deal with. For example, the sewer system in part of St. Norbert was flowing flow without any residents as a result of a dyke breach. This problem had to be rectified prior to letting anyone return home in order to prevent widespread basement flooding in St. Norbert. In all areas, restoring gas service took longer than to shut it down because service personnel had to relight all appliances. By mid-May, 97% of the evacuated residents had returned home.

Street Damage and Repairs

Total damage to streets and boulevards throughout the City as a result of the flood is estimated at $9.0 million. Consulting engineers were engaged to define the damage and repairs necessary. Repair work will be complete by the end of the construction season, including approaches and private property.

The Provencher Bridge

The Provencher bridge was closed to vehicular traffic for two months due to flood damage. Repairs to the bridge cost $700,000.

Damage to Riverbanks

Flood damage to riverbanks is estimated at between $10 and 30 million. The total damage will not be known until late October when the river level is allowed to drop to its winter level and damage can be better assessed. At that time a more complete estimate of damage to riverside infrastructure, such as pumping stations, will be prepared.

Costs

The total estimated flood related costs in the City of Winnipeg are $47 million, excluding riverbank erosion damage. The $50 million is made up of flood fighting and clean up costs ($24 million), evacuation costs ($5 million) and infrastructure damage ($18 million). The City's share of these costs is expected to be approximately $10 million.

AGRICULTURAL PREPARATIONS FOR THE FLOOD OF 1997

A. Previous Experiences, Advanced Preparation and Lead Up

The 1979 flood was viewed widely as the benchmark from which all future planning should occur. In addition, farmers and rural residents had a vivid and clear picture from memory of how a flood of this magnitude affected their property.

In the early 1980's flood proofing programs were offered to farmers and livestock producers. These programs provided for raising their building sites and/or diking them to protect them from flooding to the 1979 level plus 3 feet. In addition, all new construction was required to have protection to this level as a condition to obtain building permits.

In 1996, there was a flood threat but only minimal flooding occurred. It did serve as a recent warning that people could identify to when the 1997 flood loomed.

By late January, it was evident that an abnormal amount of snow was on the ground in the entire Red River Valley. Rooftop drifts of snow were evident everywhere. The snowstorm of April 6 only compounded the situation by putting an additional huge quantity of snow on the ground.

In the immediate lead up to the flood, the television images from Grand Forks flooding sensitized everyone concerned that 1997 would be the Flood of the Century.

B. Early Planning and Preparation Activities

In January, efforts were under way to begin assembling data and information on the numbers and types of livestock that were present in the potentially affected areas. It included information such as elevation, location, diking, names, telephone numbers, and details of the livestock.

In mid-February, flood awareness meetings were held in Domain, Morris and Letellier. These meetings were a cooperative effort of several departments and agencies but coordinated by the EMO contacts for Manitoba Agriculture. Presentations were given by representatives from Agriculture, Natural Resources, Environment Canada, Highways and Transportation, Canadian Wheat Board, Manitoba Pool Elevators, RCMP, Manitoba Emergency Management Organization (MEMO) and local municipalities. Although the targeted audience was grain producers, these meetings were open to all and were intended to be of value to all farmers including livestock producers. Because of the difficult winter, grain transport to the ports was slowed and producers were concerned as a result. Renewed efforts were then made to get the grain out of danger.

During March and early April additional information was gathering with respect to the livestock and poultry in the potentially affected area. Organizational meetings were held, staff requirements and briefings were dealt with. During this period additional information was disseminated to producers via local radio and weekly newspapers.

C. Immediate Activities

Following an organizational meeting in early April, agricultural representative offices agreed to call threatened livestock producers to advise them of the flood potential update for their information. A survey form was developed and utilized when contacting producers. As the flood threat became more imminent, the calls were repeated on an emergency basis to re-advise the most threatened producers of the danger and what the MEMO recommendations were with respect to evacuation. By April 22, producers in affected areas were shoring up either their dikes or making plans to move. Most of the livestock movement occurred from April 22-30.

Because of the widespread knowledge of the flood threat, offers of help and livestock accommodations came from many sources, Alberta to southern Ontario. A major activity centrally was to get this information to staff and in turn the livestock producer. A major activity for regional staff was the process of assisting producers in making their decisions of whether to stay or move their livestock.

A general, pattern of evacuations seemed to occur. The beef herds and there were only a few were moved early to higher ground except in the Grand Point area. The dairy herds generally moved to other locations when they realized the magnitude of the flood. They often were in older and lower locations. For swine, the larger sow herds generally stayed in place because their building sites were of recent construction and able to high water. Many of the grower-finisher pigs, however, were moved to other locations. Some of the poultry flocks were able to stay depending on elevation but several flocks (layers and broilers) were faced with emergency slaughter or evacuation.

During this period, good cooperation was received from the commodity boards with respect to providing data and information on their clients. In some cases, producers dealt directly with their commodity board to obtain information on transport and receiving sites. One dairy producer for example offered to receive up to 100 cows.

Starting with a list of known livestock producers, a running table tabulation of producers in the affected area was maintained until it was evident all animals were safe. This was coordinated with a series of ownership maps in the affected area. As a result of good cooperation and coordination of regional staff with producers, there was little or no death loss that was directly attributable to the Red River flood. Livestock losses that were known to have occurred were some birds during moving and a boar that was reported to have been shot because of difficulty in handling.

It became apparent late in April, that several larger livestock operations (including the University) had no immediate plans for evacuation. They fully intended to stay in place and continue operations. Because of their facilities, elevations and advanced preparation they felt, this was the best alternative to protect their livelihoods. In the end, they were proven right.

To assist producers that were staying, hastily developed, guidelines were developed to assist producers to do this. See Appendix A. In addition, a pass system was developed in cooperation with Natural Resources to accommodate those producers who were staying on the site.

Following the April 6 blizzard, media reports contained stories of 100,000 cows that were to be coming down the river. This proved to be highly erroneous. Never-the-less protocols were developed and put in place to meet such a threat. (Appendix B) The only dead encountered were 3 or 4 sites with individual local animals that were found and had died of causes unrelated to the flood.

There were animals that died because of flooding but these instances were limited to flash flooding as local tributaries rose unexpectedly because of ice jamming at bridges and culverts. This occurred in 2 or 3 instances and about 90 pigs were lost in one case and several calves in another.

The Potential Overflow Area in McDonald Municipality was treated as a special case. Although this area was behind a dike, there was concern about whether it would hold. As a result, preemptive evacuation was instituted. For those staying, passes were given on a case by case basis of evaluation.

The Red River Flood also became a media event. Requests for information came from 3 or 4 local radio stations, the national TV networks and local and national newspapers including a Dutch agricultural weekly paper. In order to insure consistency of information and prevent numerous people from having to deal with the media, only one person from Agriculture acted as the media contact.

D. Activities During Peak

By May 1, the Red River Valley was at or near peak flood conditions. At this time all preparations that were to be made were made and it was a matter of generally maintaining the position. Consultations with various producers were made on an as needed basis. Media interviews were also given.

In terms of operations, the Recovery and Reentry procedures were developed and the questions relating to compensation for losses began to be discussed.

HIGHLIGHT AND OBSERVATIONS

A. Positives

1. The advance public meetings in February were proactive and served to help get people in agriculture focused on the emergency that was coming.

2. The 1996 flood experience and the creation of various databases served staff well in 1997.

3. The participation of various agencies early in the process such as Environment Canada and the Canadian Wheat Board was important.

4. In contrast to 1979, the use of cell phone technology and the Internet was very useful. They are quick and convenient and both are able to cover a wide audience. Many producers have cell phones and Internet access. However, it must be noted that the cell phone system was near peak use and at times it was overloaded. The Internet although useful for distributing information is not yet available in all rural offices.

B. Issues

1. *The right to protect one's livelihood.* Conflict arose between MDA staff/producers and MEMO's broad sweeping evacuation orders.

2. *Who had authority to do what and at what level?* Multi-levels of authority added to complexity of the situation - interdepartmental, local and municipal authorities, provincial, RCMP, MEMO, Army and PFRA.

3. *Authorities' & Liabilities* - No linkage existed between decisions made by officials in charge and financial liabilities and consequence incurred by those following orders.

4. *Staff Orientation* - MDA staff replacements not always fully oriented before relieving tired front-line personnel.

5. *People and relationship* - Late night and unnecessary phone calls to producers, placed a strain on goodwill relationship between staff and clients, especially Ag Reps and their clients. There were reports of MEMO officials being welcomed in some places. While in others, they were the targets of frustration and anger.

C. Negatives

1. Staff was concerned about a lack of field communications such as fleetnet radios, cell phones and Internet access.

2. *PFRA/MDA relationship* - There may have been problems and confusion with respect to jurisdiction and motivation. Initially, relationship and team efforts were shaky.

Conclusion

The 1997 Flood of the Century was a disaster and caused considerable damage to property and infrastructure. What is obvious is that where adequate preparations were made the damage was minimized. This included those producers who stayed in place or made a timely evacuation.

Guidelines and questionnaire for those livestock producers intending to remain on livestock farms in the 1997 flood area.

1. Farm name and / or farm owner

   Farm location; Section; Township; Range

2. Names of adult people that are remaining. Suggest that only required maintenance personnel would remain.

3. What are the kind and number of livestock? Indicate sows, feeders, cows, horses, etc. and the approximate number of each.

4. What is the expected flood level at your farm?

   What is the level of protection your farm has been prepared for?

5. Quality of Protection; is it a raised pad, dike or sandbags? If it is a dike how old is it? What is the quality?

6. What is the access to the outside? It should be by boat if road access is not available.

7. Are potable water, food or feed and medication available and in place for up to 21 days of isolation for personnel and livestock?

8. Are wireless communications available?

9. Is back up power available? Standby diesel/gas generator or PTO generator is suggested. It should have sufficient capacity to maintain operations and sufficient fuel should be in place. Is there sufficient pumping capacity for protection behind dikes?

10. Is rooftop signaling equipment available?

    Use a white blanket to signal, "We are here and OK"; use a colored blanket to signal, "We are here and need help" for daytime use. At night use a flashlight to signal overflying aircraft directly.

GUIDELINES FOR HANDLING DEAD ANIMALS DURING A FLOOD EMERGENCY

GENERAL

Priority - Dead animals are a relatively low priority during an emergency. The first priority is human safety. The preservation of livestock and property are usually second and third priorities. Dead animals may constitute a public health and environmental threat but in an emergency other priorities take precedence.

The Farm Practices Guidelines have information on ordinary policies and procedures. The owner has the primary responsibility under most cases.

Where the owner is unknown, the Rural Municipality has primary responsibility for retrieval, removal and disposal of animal carcasses. They may, however, request additional assistance via Manitoba Emergency Management Organization (MEM0).

Retrieval - During any retrieval operations, human safety must be considered as paramount. Recovered animals should be moved to a temporary holding facility such as a land fill site until they can be taken for rendering and/or disposal.

Disposal - Rendering is the preferred method of disposal but other methods are acceptable for smaller animals providing they are within the recommendations of the Farm Practices Guidelines. Rothesay in 1997 has a program of rural pickup but they want carcasses collected to a staging area and do not want to collect small lots. They will not send their trucks into areas where roads cannot be traveled on easily. In addition, the carcasses cannot be badly decomposed.

Contact - The Veterinary Services Branch of Manitoba Agriculture will act as the lead agency in cooperation with the Animal Health Division of the Canadian Food Inspection Agency. Manitoba Environment will be involved especially where the owner of the dead animals is known to enforce compliance for retrieval and disposal.

Flood 97

Negatives

- Lack of communication technology and system in the field. Internet hookups at the regional level would have proved invaluable in providing timely and accurate info. Cell phones were not 100% infalliable.

- PFRA/MDA relationship. Problems with jurisdiction. No sense of team fighting the same battle.

Flood 97

Issues continued

- Staff replacements required more timely information and training to relieve tired front line personnel.

- People and relationships. Phone calls to producers regarding evacuation orders placed a strain on goodwill relationships between staff and clients. EMO officials welcomed in some places and in others the target of frustration and anger

Flood 97

Issues

- The right to protect one's livelihood. Conflict arose between MDA staff/producers and EMO's broad or sweeping evacuation orders.

- Who had authority to do what at what level? Multi levels added to complexity of situation - interdepartmental, local, regional, provincial, RCMP, EMO, army

- No linkages existed between decisions made by officials in charge and financial liabilities incurred by those following orders.

Flood Debriefing Highlights

Positives

- 1996 flood experience and the creation of a database at that time served staff well in 1997
- Advance public meetings in Feb/97 saw 350 producers attend what they saw as proactive measures by govt.
- Outside agencies involvement like CWB right from the start in Feb.

ABSTRACT

For '97 CWRA Symposium - Red River Flood

Red River Valley Town Dikes Preparation:

This presentation will cover the preparation work and flood fighting operational activities that were undertaken in the eight ring-diked communities of the Red River flood plain whose flood protection facilities are maintained and operated by the Department of Natural Resources.

Included will be a brief discussion of the emergency dike raising that was expedited in anticipation of record forecast water levels. An overview of the regular flood fighting operation features involved in ring-dike flood protection systems will also be described, i.e. closure of dike openings, internal drainage and pumping, dike patrol and monitoring, evacuation and re-entry of residents, closure removal, clean-up and dike restoration.

prepared by: Rick Hay
Regional Engineer
Manitoba Natural Resources
Central Region

October 9, 1997

RED RIVER '97 FLOOD - CONSTRUCTION OF BRUNKILD "Z" DYKE

Guy Cooper, P. Eng.,
Regional, Construction Engineer
Department of Highways and Transportation

This government initiative was unique in that time would not permit the normal government bureaucracy. It has proven that without bureaucracy anything is possible.

On April 21, 1997 Ron Richardson, Hydraulics Engineers with the Bridges and Structures Division of the Department of Highways and Transportation alerted our Head Office to the possibility of the Morris River peaking simultaneously with the Red River at Morris and overflowing into the La Salle River drainage basin causing the La Salle River to overflow into the City of Winnipeg. This phenomenon had occurred in the past.

On April 23 Ken Gibson, Sr. Project Supervisor in Region 2 was requested by Don Kuryk, EMO Coordinator for the Department of Highways and Transportation to do field reconnaissance to determine a location for a dyke to prevent the Morris River from spilling into the La Salle River. The route chosen was based on a location that was close to the natural break between the two drainage basins and took into consideration accessibility and potential for excavation materials given the extremely unfavourable prevailing conditions. It encompassed a combination of Provincial Roads, Municipal Roads and a Dyke Road along the King Drain.

Initial estimates based on limited and outdated field information indicated that approximately 15 miles of dyke needed to be constructed with fills ranging as high as 6 feet. Once the decision was made to proceed and actual field information was obtained, the length of dyke increased to 26 miles and fills increased by approximately 2 feet.

On April 23 at 6:15 P.M. I received a phone call from D. Kuryk requesting that I attend a meeting scheduled for 6:30 P.M. wherein I was requested to use any means conceivable to undertake construction of 15 miles of dyke within a 72 hour window of opportunity. I was assured at this meeting that Head Office was committed to acquiring anything necessary to accomplish this onerous task. I must acknowledge that they fulfilled this commitment to the utmost. We utilized dozens of the most experienced and conscientious Departmental personnel from all over the Province. Provisions were made to deliver and distribute over 300 meals twice daily to the site.

With the task assigned, Ken Gibson and I returned to our homes that evening for our last partial good nights sleep for approximately 10 days. Without knowing what construction methods could be utilized, we started phoning contractors and ordering backhoes and dozers to the site for the next morning. Bill Fisher, Chief Engineer with Hugh Munro Construction Ltd. offered to come and determine the magnitude of the project and provide his expertise in determining construction methods.

On April 24 at 7:00 A.M. D. Kuryk, K. Gibson and myself from the Department of Highways, B. Fisher, Lt. Col. Appelton of the Army, and Frank Barlishen, Head, Provincial Waterways, Water Resources Branch met on site.

It was decided that conventional earth moving equipment could be utilized in some areas, backhoes in other areas and one stretch 2 miles long would have to be done with minus 6 inch limestone. In areas where conventional equipment could be utilized, we chose high ground in farm fields for borrow excavation. D6 wide pad dozers stripped the saturated topsoil and placed it in the form of a dyke on the circumference of the borrow area to prevent infiltration of surface water. Borrow areas were excavated as deep as possible to avoid frozen material. Motor graders and dozers were utilized on the dyke fill to distribute the borrow material. Compaction was what could be achieved by the earth moving equipment, motor graders and dozers. A major naturally occurring asset in the dyke embankment material was that it was a high plastic impervious Red River Clay.

Track Type Hydraulic Excavators were utilized in areas where no borrow excavation was available. They utilized material from the berm of an existing dyke in some cases and half of the existing road in others. Backhoe material was placed in relatively large lifts and levelled and compacted with dozers.

A 1/2 mile section of Provincial Trunk Highway No. 3 which formed part of the dyke existed at projected high water elevation. Freeboard was established on this section utilizing super sand bags weighing approximately 3000 pounds each.

Over 100 trucks and 3 crushers worked 24 hours a day constructing the minus 6 inch limestone section. This section was constructed in 4 lifts with the first lift being end dumped (a very slow process).

The Army dropped flares from aircraft to provide night time lighting. Conventional earth moving equipment worked approximately 16 hour days, as there were not enough operators in the Province to double shift. Backhoes and the limestone operation worked 24 hours a day.

We staged our construction so that the west end would be done first as previous experience indicated it would be the first area to receive flood waters. Sections where borrow excavation had to come from inside the dyke were also prioritized. Areas where borrow excavation was proposed from outside the dyke were staged last as we felt we could continue to work as the waters rose.

It was also decided to build to anticipated high water level first and then establish the 2 feet of freeboard.

Bill Fisher assumed responsibility for acquiring and coordinating all equipment. He solicited the aid of Fred Finnson and Don Wiens from Taillieu Construction Ltd. to supervise the backhoe operation and David McDonald from Nelson River Construction Inc. to supervise the limestone.

On April 25 water started to encroach upon the dyke at the east end (so much for previous experience). It rained at night on April 25th and 26th shutting down conventional earth moving equipment. Backhoes and the limestone operation continued through the rains.

On April 27 we completed the first lift of limestone at approximately noon and subsequent lifts proceeded much more rapidly as a circulation was put in place. On April 28 water started rising rapidly on the east end and south winds were forecast. All backhoes as well as as much earth moving equipment that could be accommodated were deployed to the east end. At 8:00 A.M. it was necessary to cut a Municipal Road to prevent a breaching of the existing dyke we were tying into. At 3:00 P.M. conventional equipment was again shut down by rain. It was able to resume work by 8:00 P.M.

By April 29 we had achieved the high water level on the majority of the dyke. Some sections were quite suspect in regards to structural integrity. At this point we started shoring the deficient areas and adding the 2 feet of freeboard.

On April 30 earth was basically moved and 631 motor scrapers were shut down. Other equipment continued shoring deficient areas and establishing freeboard.

On May 2 all equipment was shut down and the constructed dyke was accepted by Water Resources.

Coffer dams with gated pipes were subsequently constructed on the downstream ends of the Manness and Domain Drains to control the release of the water. A controlled release commenced on May 17.

Several initiatives including straw and rope, wrecked school buses, large round bales, and poly-plastic and snow fence were utilized to resist/reduce wave action.

The cost to construct the dyke was approximately $7,000.000 exclusive of wave action initiatives, standby during the flood or restoration costs. It is estimated that approximately 700,000 cubic meters of earth and 140,000 tonnes of limestone were utilized in the construction.

A total of 53 individual contractors provided 278 units of earth related equipment, over 100 trucks and 3 crushers. The mobilization of this amount of equipment in such a short time frame is a testament to the ability of our Construction Industry to respond to a challenge.

Following is a summary of equipment utilized:

Lowbeds	30
Cats and Scrapers	26
Hydraulic Excavators	70
Track Type Tractors/Dozers	79
Wheel Loaders	12
Rock Trucks	15
Motor Graders	12
Rubber Tired Scrapers	34
Trucks	100
Crushers	3

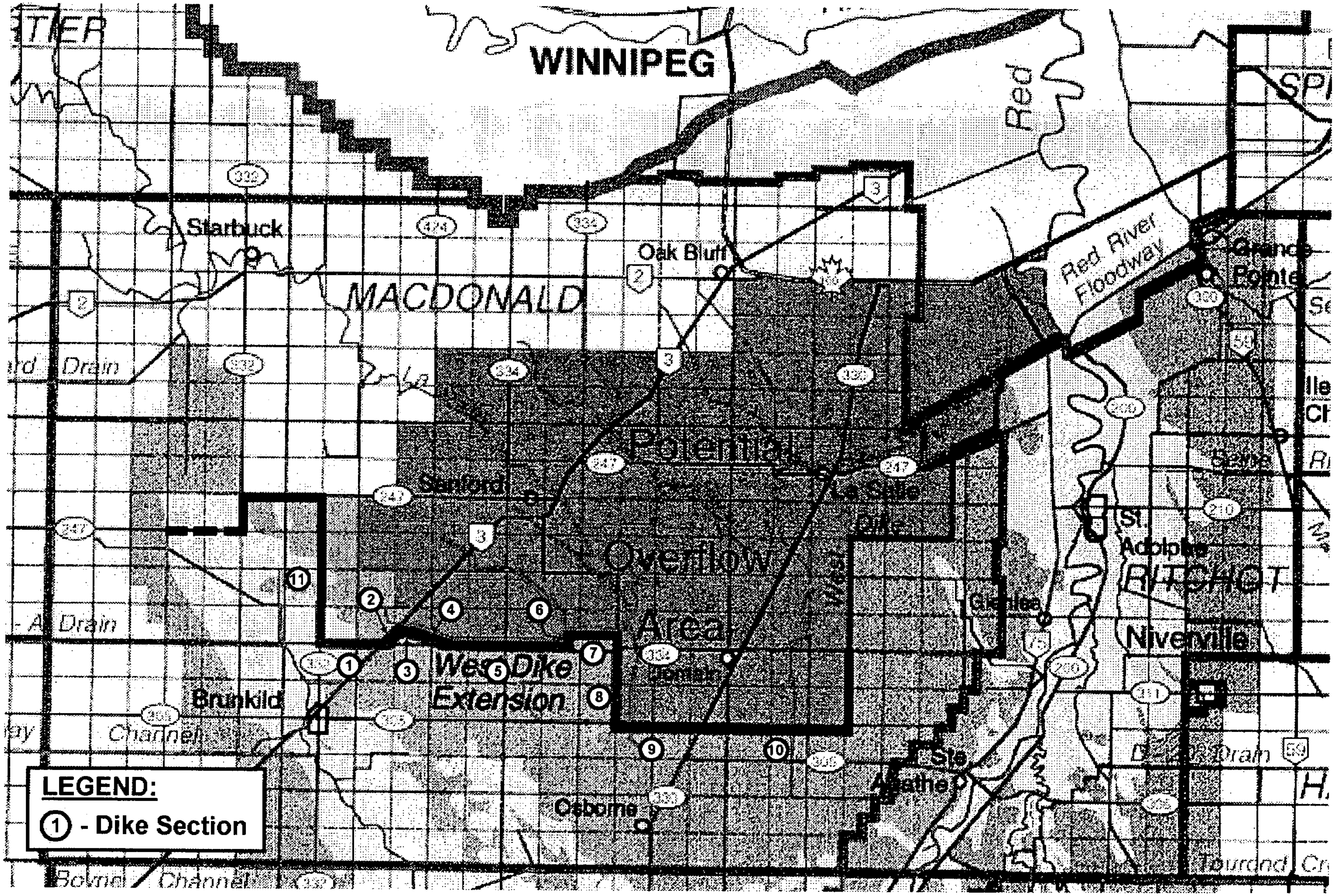
I wish to acknowledge the tremendous response from the entire Heavy Construction Industry, the dedication and cooperation of the many Departmental Staff involved in the project, and the willingness of the Army to assist wherever possible. Partnering between Government and The Industry was demonstrated to the fullest. There was no need for a formal partnering agreement. There was a mutual trust and respect combined with a common goal.

I am extremely proud to say that I was part of a great team- The Z DYKE TEAM - which accomplished a feat that will be difficult to surpass.

May, 1997

Site Plan of Z Dike

Manitoba Highways and Transportation



THE TASK FORCE

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Abstract
In late April the Province of Manitoba struck a Task Force to help manage "The Flood of the Century." This paper describes a few of the key activities of the Task Force.

Introduction
Southern Manitoba is well acquainted with flooding. Significant events (i.e., greater than 80,000 cfs) have occurred in 1950, 1966, 1974, 1979, and 1996. Nevertheless, the "Flood of the Century" delivered a quantity of water like non other in living memory. Figure 1 shows the area of southern Manitoba inundated by flooding in 1997 relative to that in 1979. As the severity of this flood became apparent, so did the potential for it to outflank the then existing west dyke of the Red River floodway inlet control structure. This would have lead to serious flooding in the communities of Sanford, La Salle, Domain, and St. Norbert. It would have also significantly increased the flow in the La Salle River. As the La Salle River is confluent with the Red River downstream of the Red River floodway inlet control structure, the outflanking of the west dyke also posed a serious problem for the City of Winnipeg. The need to extend the west dyke was clear. Recognizing that we were truly in "uncharted waters" the Province struck a Task Force to assist with the management of the flood of 1997.

Composition of the Task Force

The Water Resources Branch headed up the Provincial Task Force with representation from:

1. Manitoba Natural Resources, Water Resources Branch,
2. the City of Winnipeg,
3. the Canadian Armed Forces Engineering division,
4. Acres International,
5. Manitoba Hydro, and
6. The University of Manitoba.

Table 1 provides a summary of the members of the Task Force and their respective affiliations.

Table 1. Summary of Task Force Members

Name	Affiliation
Rick Bowering	MB Natural Resources, Water Resources
Jay Doering	University of Manitoba
Bruce Harding	Acres International
Bob Harrison	MB Natural Resources, Water Resources
Eugene Kozera	MB Natural Resources, Water Resources
Paul Lagasse	City of Winnipeg
Greg Pada	Canadian Armed Forces Engineering Division
Randy Raban	Manitoba Hydro
Steve Topping	MB Natural Resources, Water Resources
Alf Warkentin	MB Natural Resources, Water Resources

Technical staff from the home agencies supported each Task Force member.

Terms of Reference

The Task Force had three primary responsibilities:

1. Appraise the current flood situation and identify what was likely to occur to assist in the daily operation of the flood control works.
2. Identify potential events that could affect the current flood situation such as dyke breaches, wind setup, heavy rainfall, etc. This information drove major capital works and flood measures such as the extension and reinforcement of the west dyke and construction of the secondary dyking.
3. Identify potential emergency situations or developments and communicate to Emergency Measures Organization (EMO), the City of Winnipeg, and Municipalities. This information initiated evacuation and re-entry efforts.

The Task Force met every day throughout the flood to carry out these objectives and then communicate this information to a designated official and/or spokesperson from the City of Winnipeg, Provincial or Municipality. In addition to this, daily briefings were given to EMO and the Armed Forces at the Legislature.

Synopsis of Task Force Activities

The hasty construction of the west dyke extension, more commonly known as the Brunkild or Z-dyke, was an initial focus of the Task Force. As a result, a low-level aerial reconnaissance of the flooded area south of the west dyke as well as a ground level site investigation was conducted. It had been determined from topographic information that section 8 would be the location of the deepest pool of water against the Z-dyke (refer to figure 2). It was this area of the Z-dyke that was shielded from wave action by the school buses deployed along Hwy 305 (refer to figure 3). A breach analysis of the Z-dyke at this location, undertaken by Acres International, indicated that a sustained flow of 40,000 cfs would occur through the La Salle River valley. These conditions were run for a sustained wind of 60 kph from the south. A statistical analysis of wind data for the months of April and May indicated that a 60 kph wind from a southerly direction had less than a 0.5% chance of occurrence. Combining the breach flow into the La Salle River valley with that passing through the floodway gates would lead to wide spread flooding within the City of Winnipeg. The Task Force then devised a management strategy that would maintain a flow of 79,000 cfs through the City of Winnipeg, which is equivalent to 24.5 ft at James Avenue, by slowly increasing the flow in the floodway (figure 4).

A breach of the Z-dyke at section 8 would have led to serious flooding in the communities of Domain, La Salle, St. Norbert, and Sanford. It was for this reason that these communities were evacuated. Although the risk of a breach was small, the possibility necessitated evacuation. To ignore this possibility would have been reckless.

Aerial reconnaissance indicated that section 10 of the west dyke was exposed to very large velocities as a result of the flow convergence at this location. A breach analysis (figure 5) was also performed for this location. Due to the shallower pool of water behind this section of the dyke, the breach analysis indicated a sustained flow of approximately 25,000 cfs. This section of the Z-dyke subsequently was protected by riprap, and hay bales.

Thursday, May 1st, 1997 marked a historic day in the operation of the floodway and proved yet again that we were truly in "uncharted waters". It was the day that James Avenue water level rose to 24.5 feet. If levels in Winnipeg were permitted to rise above 24.5 feet there is a considerable risk that the primary dykes may fail, thus resulting in extensive flooding in the city. Therefore, the floodway inlet control structure was operated so as to maintain James Avenue at 24.5 feet. In light of this action the Free Press headline of Saturday, May 3rd, 1997 read "Suburb sacrificed to spare Winnipeg".

To monitor water levels along the west dyke and Z-dyke a series of water level gauges were installed (figure 2). These levels were useful for assessing breach potential and re-entry timing. Figure 6 shows the wind speed, wind direction, and water levels at gauges G and H (Z-dyke section 10) which was an area of branch concern given the depth of water and relatively high velocities at this location. The fluctuation in the observed water levels is the result of wind setup and sadden associated with winds from the south and north, respectively.

Presentations

The Task Force assembled a presentation to disseminate the conditions of the worst case scenario. The presentation described:

1. the hydraulic conditions observed from aerial reconnaissance,
2. the characteristics of the Z-dyke,
3. measures undertaken to protection of the Z-dyke,
4. the mechanisms by which a breach could take place,
5. the possible wind induced setup and wave heights at the Z-dyke,
6. the probable rate of flow through a breach,
7. the containment of a breach,and
8. the management of the Red River floodway inlet control structure to "offset" the impact of a Z-dyke breach on the City of Winnipeg.

Presentations were given to:

1. Provincial Ministers at the Legislature,
2. The City of Winnipeg,
3. Emergency Measures Organization, and
4. Officials from rural municipalities.

Closing Remarks

The flood of 1997 has left an indelible impression on the residents of southern Manitoba. It will be long remembered by those directly and indirectly affected. Members of the Task Force will also remember the long days and short nights, the devastation witnessed during the low level aerial reconnaissance flights, and cell phones.

Acknowledgments

Some of the calculations I performed would not have been possible without the support I received from several of my graduate students. In particular, Andrew Baryla spent many hours coding the algorithms to compute wind-setup on the Z-dyke. A number of my other graduate students (viz., Devon Danielson, Ninel Gonzalez, and Pamela Hans) also assisted with calculations. Thank you!

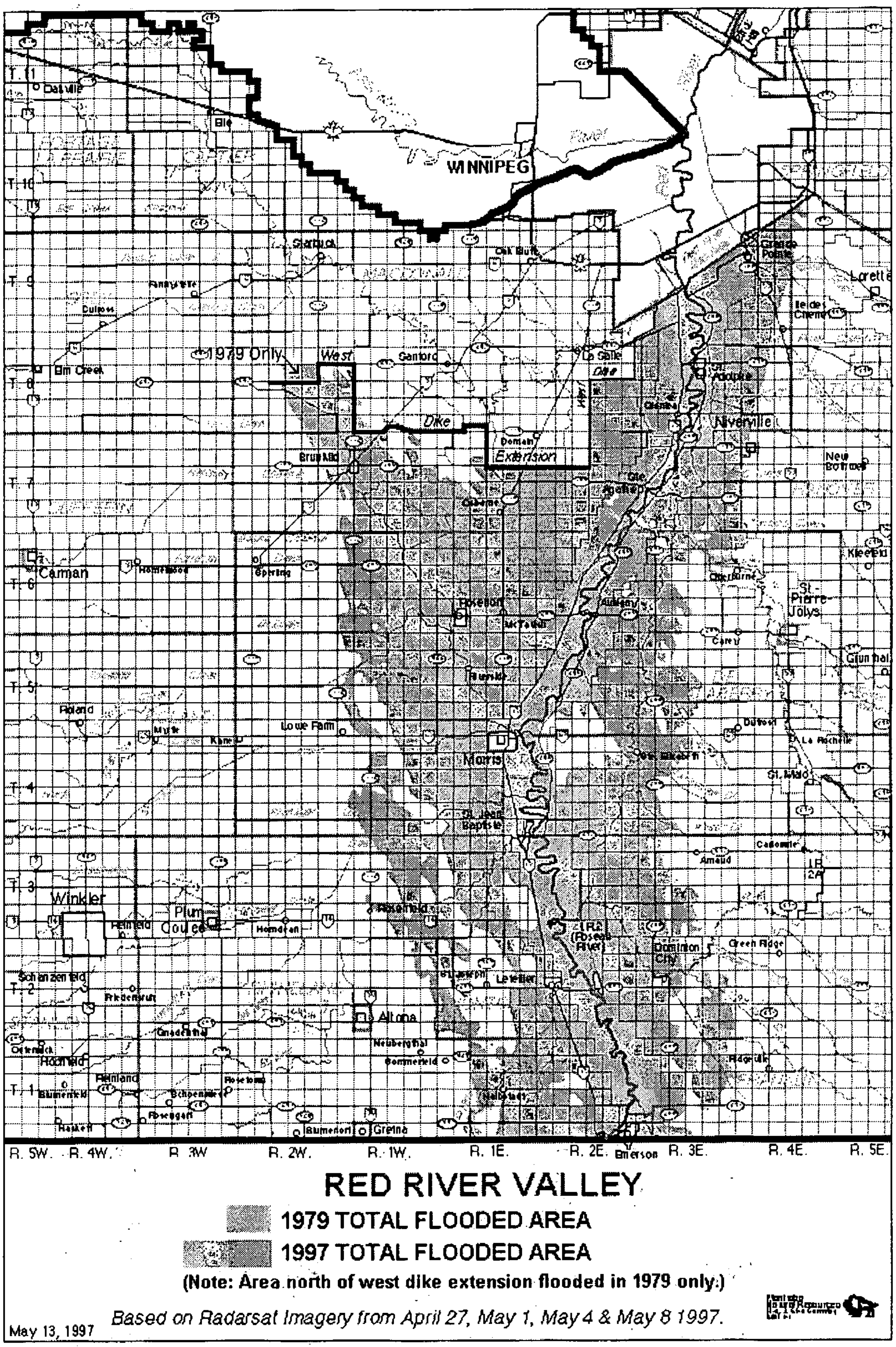


Figure 1. Radarsat image showing the area of southern Manitoba flooded in 1997. The lighter shading shows the area inundated by the 1979 flood.

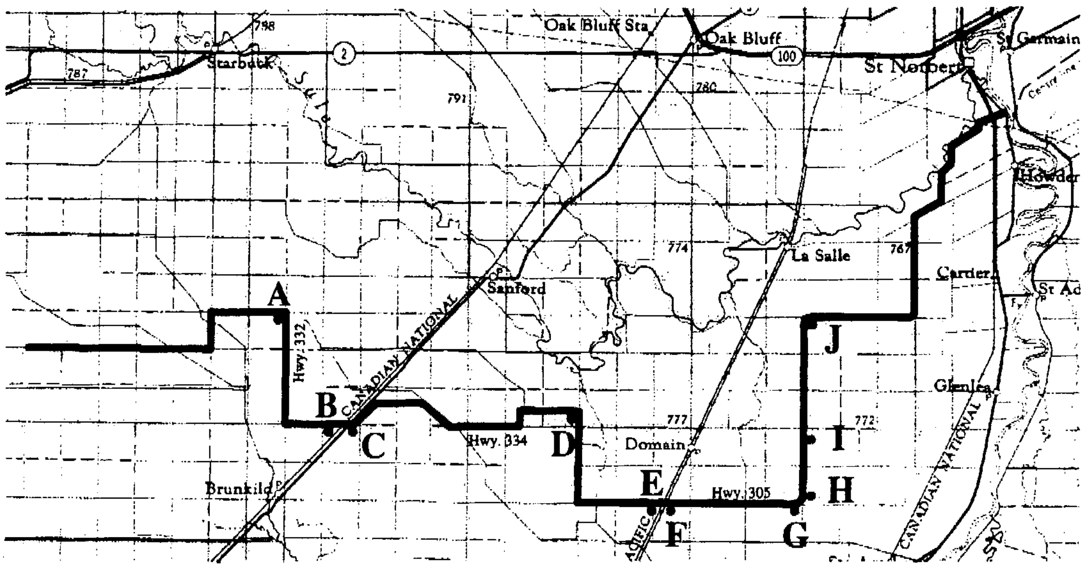


Figure 2. Location of the west dyke, west dyke extension (Z-dyke), and temporary water level gauge locations (A to J). The original west dyke ended at location H. The extension was constructed from G to east of A as shown. Note: section 8 of the Z-dyke is the north-south oriented section of the dyke south of gauge D and section 10 is located between gauges F and G.

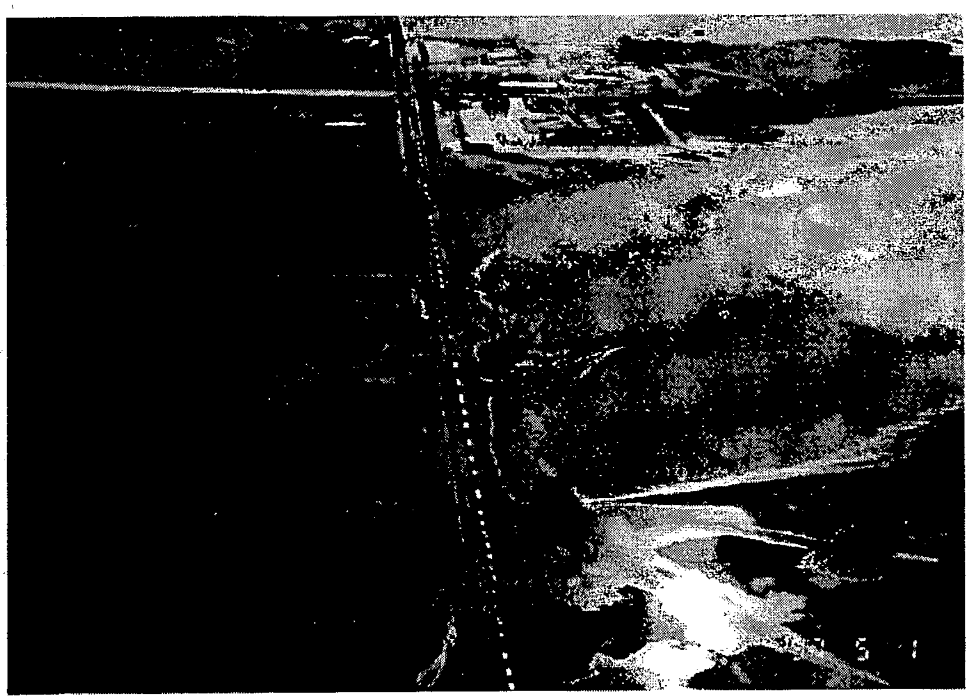


Figure 3. Aerial photo of the school buses deployed along Hwy 305 to protect section 8 of the west dyke extension from wave action.

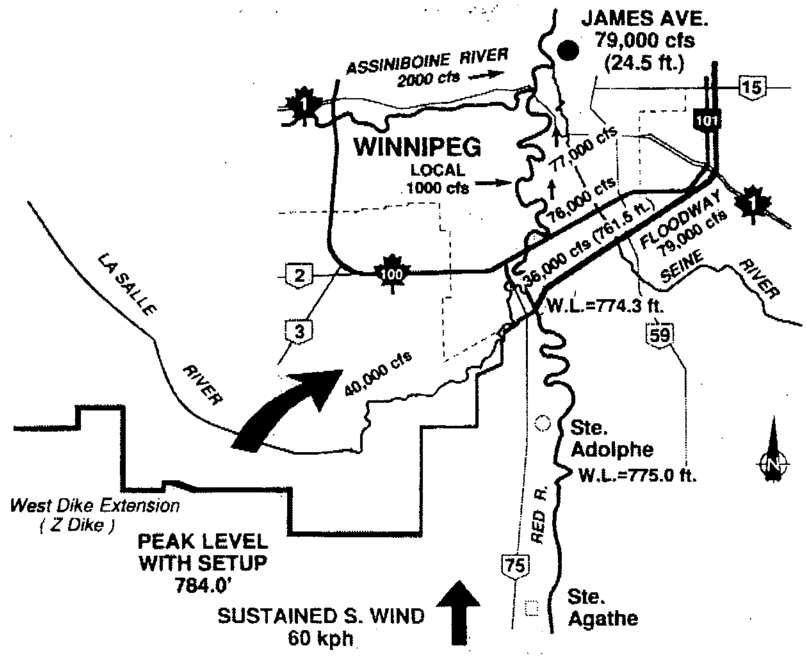


Figure 4. Worst case scenario of a multiple breach of the Z-dyke near section 8. Conditions shown are steady state, 5 days after the formation of a breach.

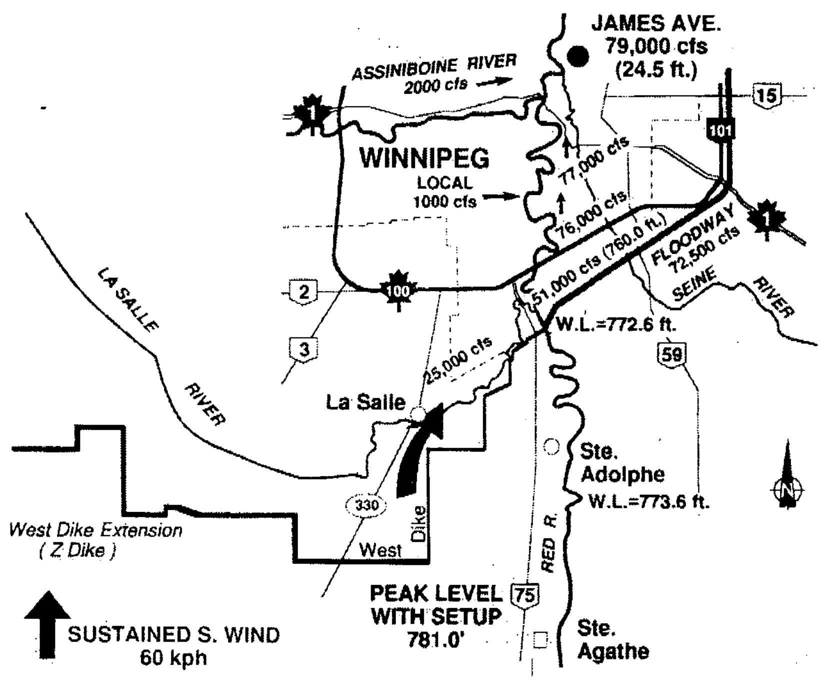


Figure 5. Worst case scenario of a breach of the west dyke near section 10. Conditions shown are steady state, 5 days after the formation of a breach.

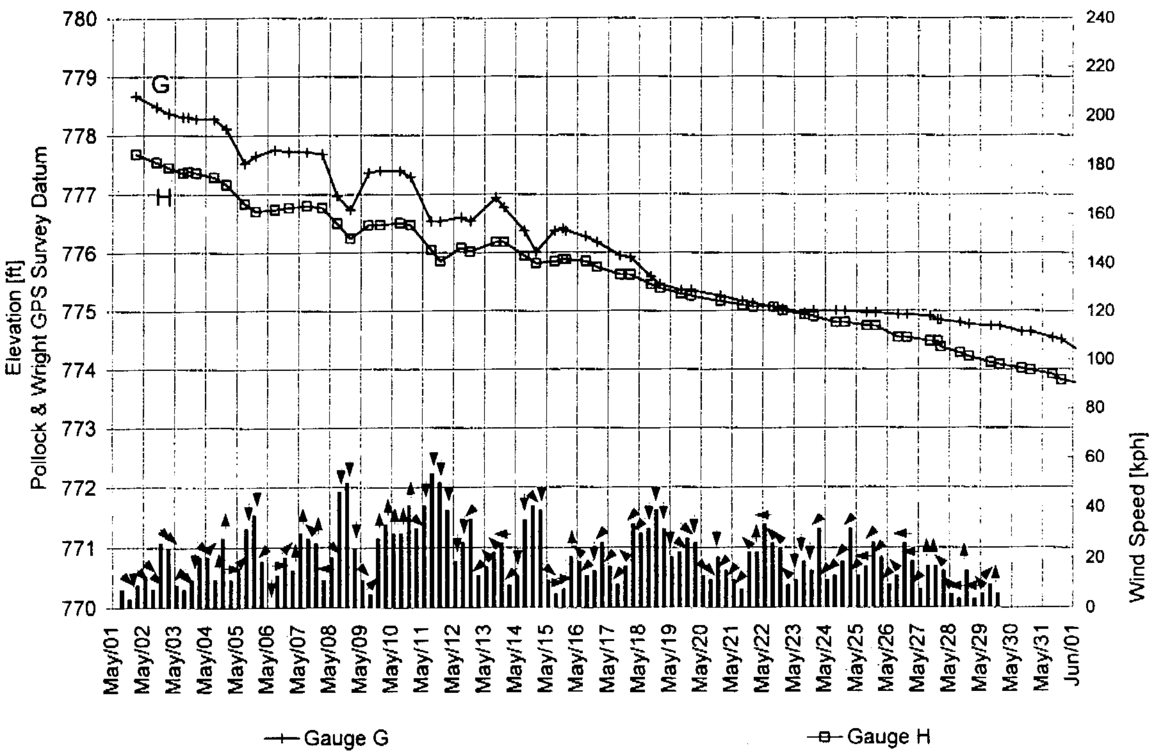
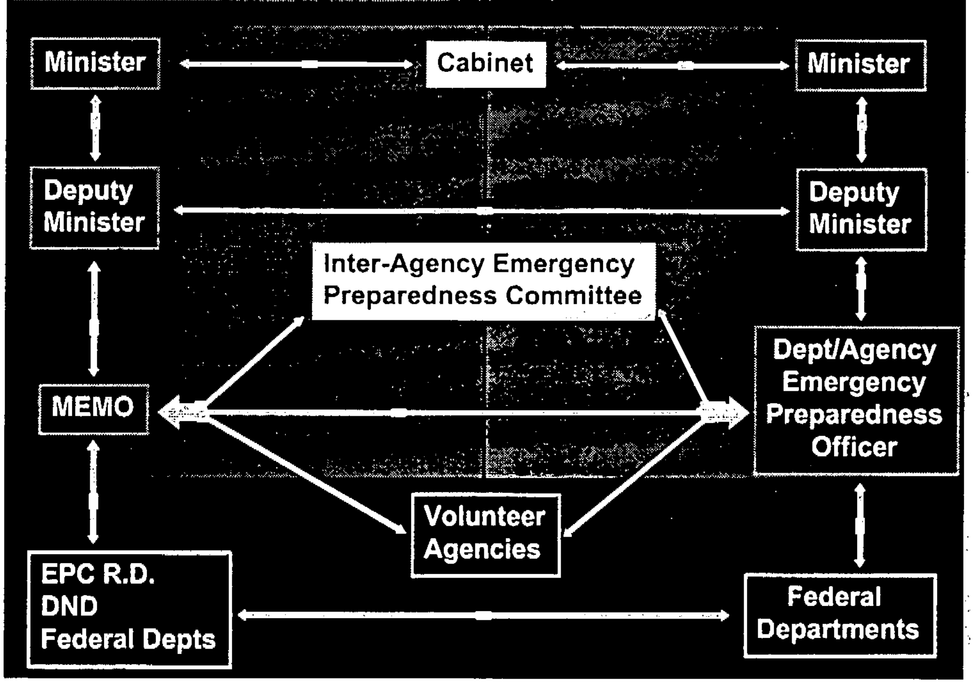


Figure 6. Water levels at gauges G and H along the Z-dyke. The bottom of the plot shows the wind speed and direction (given by the direction of the arrow). Data courtesy of Terry Miles, Hydraulic Engineering and Operations Department, Manitoba Hydro.

Emergency Preparedness

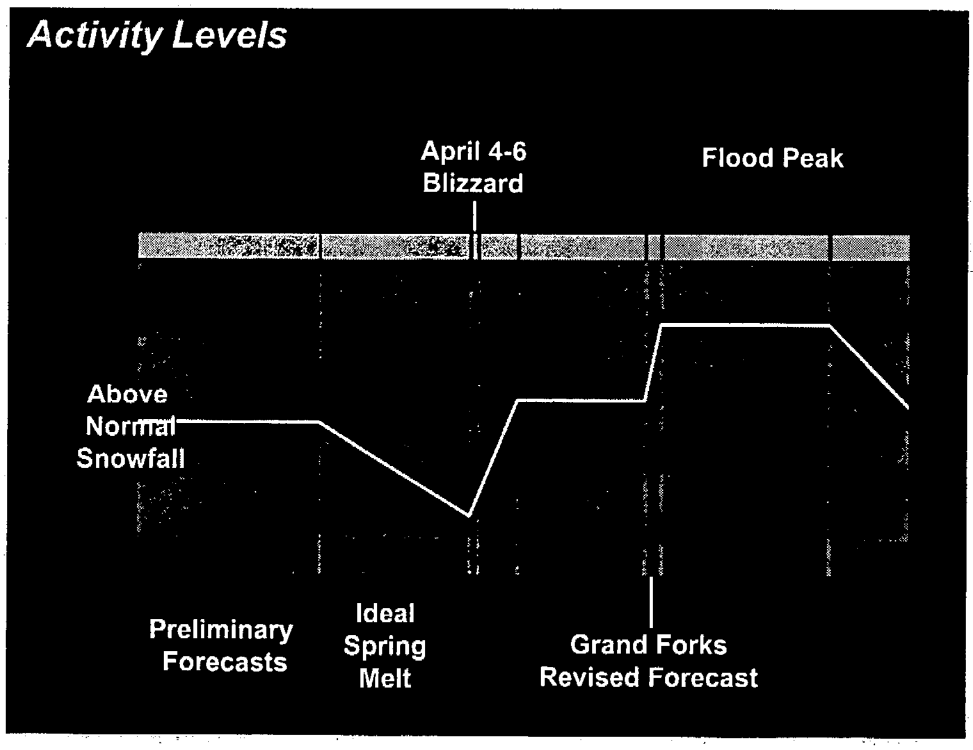
- Emergency Measures Act
  - Manitoba Emergency Plan
    - Department Emergency Plan
  - Community Emergency Plans
- Training & Education
- Exercises
- Experience - 1996 Red River Flood

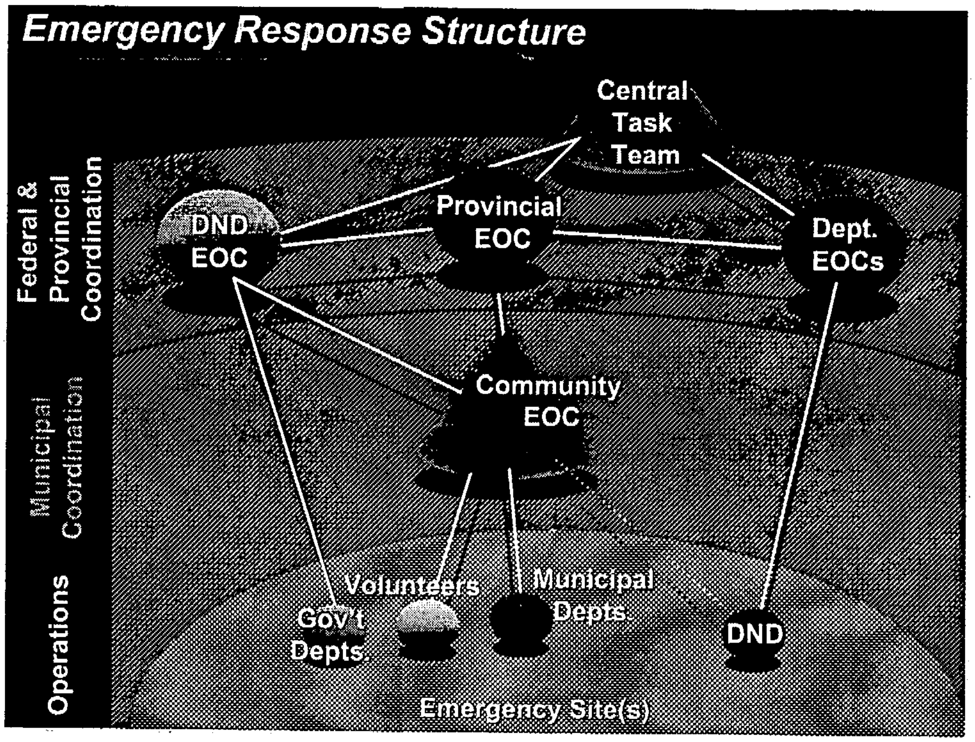
Emergency Preparedness Structure



Pre Flood Activities

- Interagency Meetings
- Flood Forecasts
- Contingency Planning
- Agriculture Movements
- Sandbagging
- Dike Inspection / Preparation
- Municipal Meetings
- Public Meetings
- DFA Training

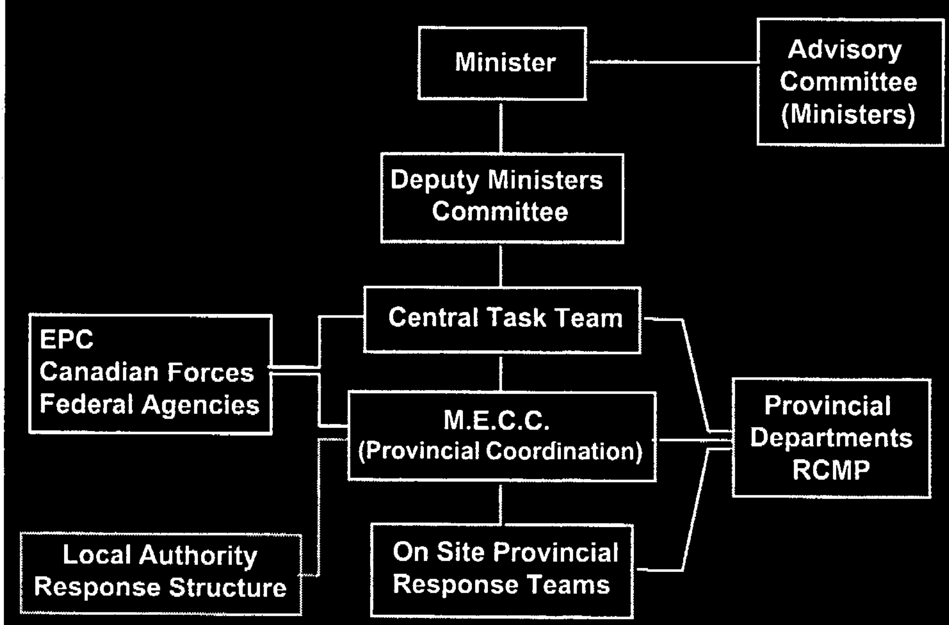

Activity Levels
April 4-6
Blizzard
Flood Peak
Above
Normal
Snowfall
Preliminary
Forecasts
Ideal
Spring
Melt
Grand Forks
Revised Forecast


Emergency Response Structure
Central
Task
Team
Federal &
Provincial
Coordination
DND
EOC
Provincial
EOC
Dept.
EOCs
Municipal
Coordination
Community
EOC
Operations
Volunteers
Municipal
Depts.
Gov't
Depts.
DND
Emergency Site(s)

Provincial Response

- Sandbag Support
- Brunkild Dyke
- Flood Monitoring & Forecasting
- Dyke Monitoring / Repair
- Security / Search & Rescue
- Volunteer Coordination
- Public / Media Communications
- Emergency Social Services
- Transportation Routing
- Communications

Provincial Response Structure



Organizational Involvement

Emergency Response

Provincial Departments

- MEMO
- Natural Resources
- Highways
- ESS
- RCMP
- Agriculture
- Health
- Environment
- Communications
- Gov't Services
- Energy & Mines
- Education

Federal Departments

- EPC
- DND
- Coast Guard
- PFRA
- Agriculture
- Agri-food Canada
- Canada Post

NGOs

- Red Cross
- Salvation Army
- Mennonite Disaster Service

Communities

- 21 Communities directly affected by the flood.

PRESENTATION BY
L. F. FRENCH
REGIONAL DIRECTOR
EMERGENCY PREPAREDNESS CANADA
TO THE

"RED RIVER '97 FLOOD SYMPOSIUM"

MANITOBA NATURAL RESOURCES
WATER RESOURCES BRANCH

OCTOBER 22 & 23, 1997
WINNIPEG, MANITOBA

"THE ROLE OF EMERGENCY PREPAREDNESS CANADA"

PRESENTATION OUTLINE

1. BACKGROUND

For almost 60 years the federal government has had some form or other of a formal emergency preparedness structure and role. In the early days and through to the early 1970's the role was to a large part directed to combatting the effects on the population of nuclear war. Since the 1970's this role has evolved to place emphasis to support to provinces and territories during times of natural and human-caused disaster. This section will briefly discuss the current federal emergency structures and role under the following headings.

- EPC Mandate & Mission
- *The Emergencies Act*
- *The Emergency Preparedness Act*
- National Organization
- National Support Plan

Mandate
"Foster better preparedness"

2. FEDERAL REGIONAL ORGANIZATION

In Manitoba federal emergency support to the province during disaster situations is coordinated through the Federal Emergency Preparedness Coordinating Committee (FEPCC). The group, chaired by EPC provides a forum for the discussion of federal emergency preparedness matters and provides the province with a single point of contact for the acquisition of federal support.

- FEPCC Mandate (*the Emergency Preparedness Act* - Section 7)
- Terms of Reference
- Participants

3. FEDERAL SUPPORT ACTIVITIES

Virtually every federal department and agency played some form of role in providing support to Manitoba during the 1997 floods this section will highlight these roles, both those that were very visible, such as that of the Fisheries and Oceans including the Canadian Coast Guard and some of the less visible such as Veterans Affairs providing support to EPC for over three weeks. This section will bring out the magnitude of national involvement in a major disaster.

4. FEDERAL DISASTER COST SHARING

Although this "Session B" is directed to "Fighting the Flood", EPC has a major role in the administration of federal/provincial disaster cost sharing. A clear understanding, prior to the event, of the cost sharing mechanisms which are in place is important to the response effort. Under this topic there will be a brief discussion of:

- The federal Disaster Financial Assistance arrangements (DFAA) and,
- The Canada-Manitoba Agreement on Red River Flood Disaster Assistance (1997)

5. LESSONS LEARNED

One of the basis rules of emergency preparedness, after an exercise or a real event, is to review your emergency plan and procedures in the light of lessons learned during the exercise or event. The following "lessons learning" will be discussed.

- The Role of FEPCC
- Communications
- Federal/Provincial Coordination and Liaison
- Accommodation for Federal Operation
- Financing of Departmental/Agency Support Operations
- Role of the EPC Regional Director

Fighting the Red River Flood of 1997
"The Canadian Forces Participation"

The Red River south of Winnipeg has a long history of spring flooding. As a result of the devastating 1950 flood, where over 100,000 people in Winnipeg were evacuated, a floodway was built to protect the city. Over the ensuing years, the floodway has proven to be very effective. Over time rural communities south of the city have also developed various methods of coping with the annual floods, ranging from temporary dikes to major, reinforced perimeter dikes encompassing entire communities. On average, these measures suffice, with the occasional requirement for additional effort. The civil authorities are well verse in these matters and are confident in their ability to react to various flood scenarios. Since the construction of the permanent flood protection infrastructure, flooding necessitated the use of the military only infrequently and in a limited role. As a result, the civil authorities and population firmly believed that they could handle the event of 1997 in stride, despite indications that significant flooding might occur.

In the spring of 1997, Southern Manitoba experienced its worst flooding in over 150 years. This disaster developed gradually; as a result, its nature and magnitude could not be accurately projected by provincial authorities or by the Canadian Forces in time to permit specific plans and commitments to be agreed upon too much in advance of requirements. Regardless, the established liaison in place continued as per normal until hard facts and requests were known.

During the winter/spring of 1996/1997, formal liaison with the Manitoba Government was maintained by the Land Force Western Area (LFWA) domestic operations cell for Manitoba. The Manitoba Domestic Operations Officer regularly attended the Provincial Inter-agency Emergency Preparedness Committee meetings and kept LFWA abreast of developments. Until 18 April, when the devastation south of the Canada/United States border became apparent, the Provincial authorities believed they would not need Canadian Forces support. This effectively constrained Commander LFWA's ability to make firm preparations in advance. Nonetheless, in early March Commander LFWA discussed Joint Force command and control architecture with National Defence Headquarters and Air Command Headquarters, and issued an initial intent.

In early April, as the probability of a request to assist increased, Commander LFWA warned Commander 1 Canadian Mechanized Brigade Group

(1 CMBG) that his formation would be assigned the task and advised other LFWA formations to be prepared to assist. At the time, there was no clear indication of what type or how much support would be requested. As a result, Commander 1 CMBG directed an infantry battalion to move its planned training from Alberta to CFB Shilo in Manitoba in order to reduce the response time if support was requested. At the same time, Air Command was preparing to relocate helicopter assets into Winnipeg on short notice.

Late in this preparation phase, the province formally requested military support. Thus began what was to become Operation Assistance. What started out as a request for one hundred soldiers to help fill sandbags for three days, quickly escalated within two weeks to a Joint Force operation encompassing approximately 8,500 personnel, 2850 vehicles, 131 watercraft, and 34 aircraft, drawn from across the entire country. This was arguably the largest domestic operation ever conducted by the Canadian Forces. It was certainly the first of this scale for many of the participants, including commanders.

Because major domestic operations tend to be unique and occur infrequently, a re-education process is often required when such operations are launched. Consequently it is important to capture and record lessons learned or re-learned and make them available for future domestic operations.

OPERATIONS

Simply stated, the Operation Assistance mission was to assist the civil authorities in Manitoba. This translated to the provision of support within deployed capabilities, against the requirements identified and prioritized by civil authorities. The Joint Force Commander established the first priority for the Joint Force as being to save lives, prevent injury and relieve suffering. The second priority was to assist with preventative measures, to include protection of property. Due to the scope of the flooding and the timing of the Canadian Forces deployment, there were limitations to the preventative work that could be completed.

CONCEPT OF OPERATIONS

There were five phases to this operation, unfolding from south to north as the water levels rose:

a. Phase 1 – Preparation. This phase encompassed tasks which were undertaken before the crest arrived. Tasks included assistance with preventative measures ie dyking, rescues, planning for and assistance to emergency evacuations and planning for large scale pre-planned evacuations;

b. Phase 2 – Support Operations. This encompassed defensive operations as the Red River crested. Tasks included emergency rescue, support to pre-planned evacuations if ordered and assistance with control of the water zone and the airspace above it;

c. Phase 3 – Stabilization. Stability operations included tasks performed while water levels remained high and threatening. Tasks included rescue, resupply and other assistance to dyked communities, dyke maintenance and quick reaction to breaches, assistance to law enforcement agencies for control of access and security in evacuated communities, and preparation for re-entry;

d. Phase 4 – Re-entry. This encompassed various engineering, labour and transport intensive tasks related to re-entering evacuated areas and re-establishing normal conditions; and

e. Phase 5 – Reconstitution and Redeployment. As the scope of the emergency returned to levels which could be manage by civil authorities, Joint Force drawdown was executed. Phase 5 began 7 May and was completed by 30 May 1997.

Fighting the Red River Flood 1997 "Canadian Forces Participation"

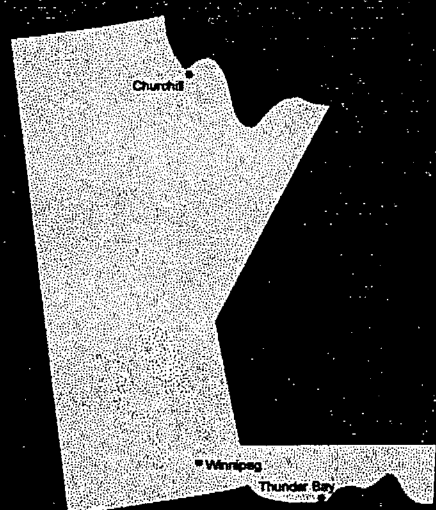
Major Brian Flynn
Detachment Commander
Land Force Western Area Detachment Winnipeg
(Manitoba Domestic Operations)

Topics

- Land Force Areas
- Liaison
- Request for Assistance
- Sequence of Events
- Activities
- Lessons Learned

Land Force Areas

Manitoba Domestic Operations Area of Responsibility

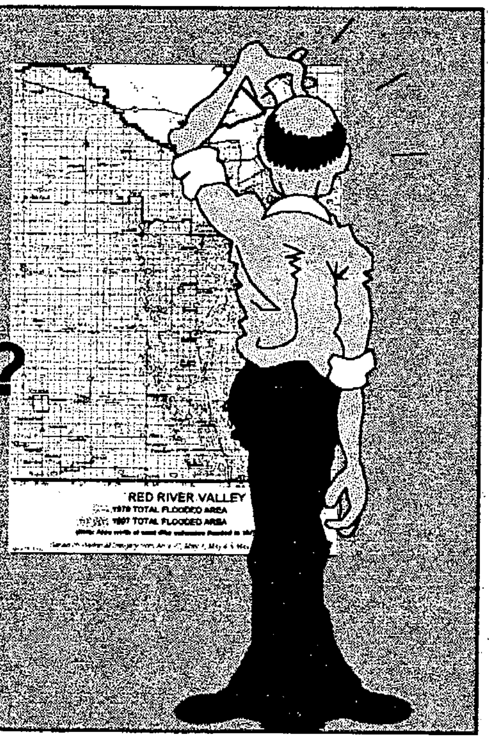


Continuous Liaison with ...

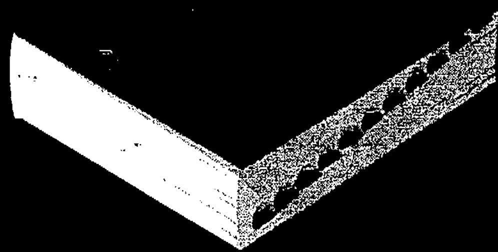
Emergency Preparedness Canada | Protection civile Canada

Manitoba EMO

What to do?
How to do it?
Who to ask?

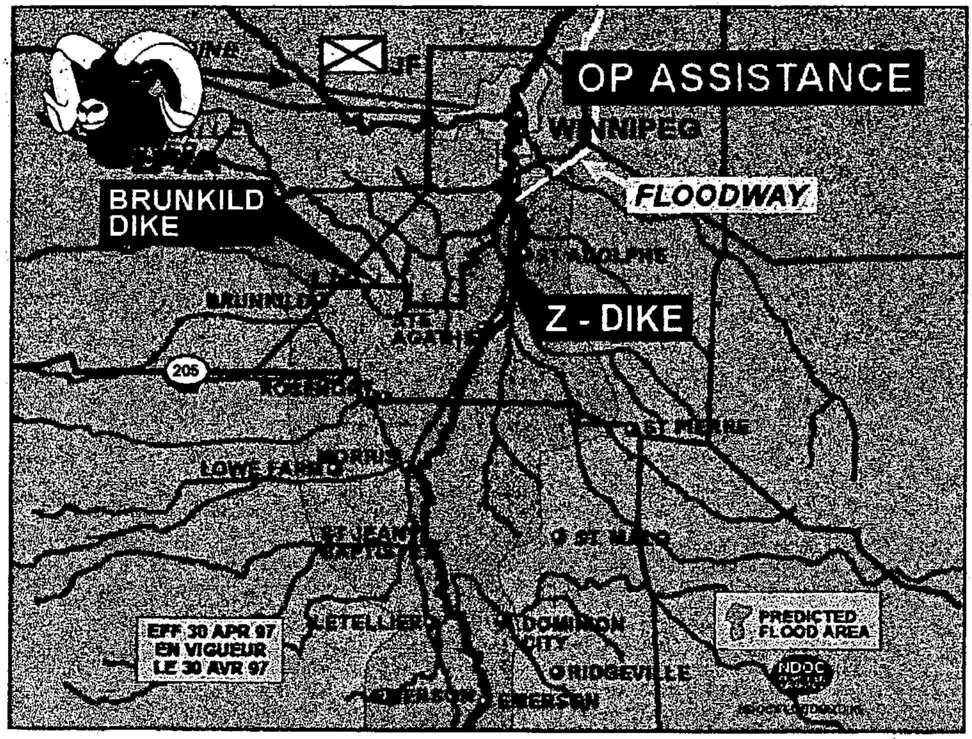


Procedures



Initial Response

OP NOAH
which quickly became.....

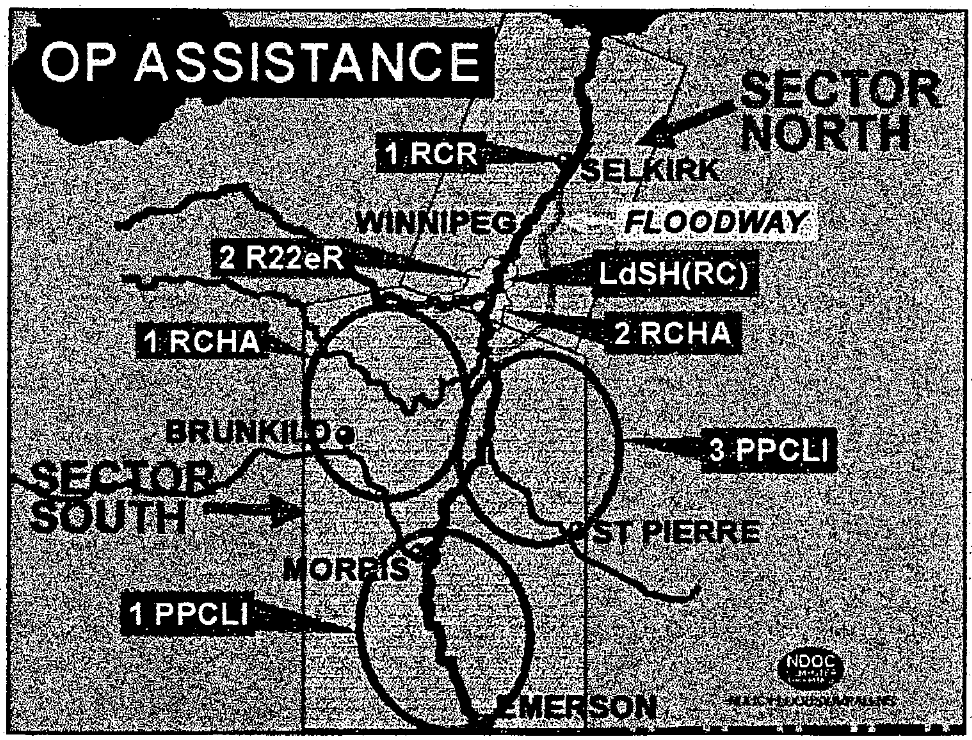


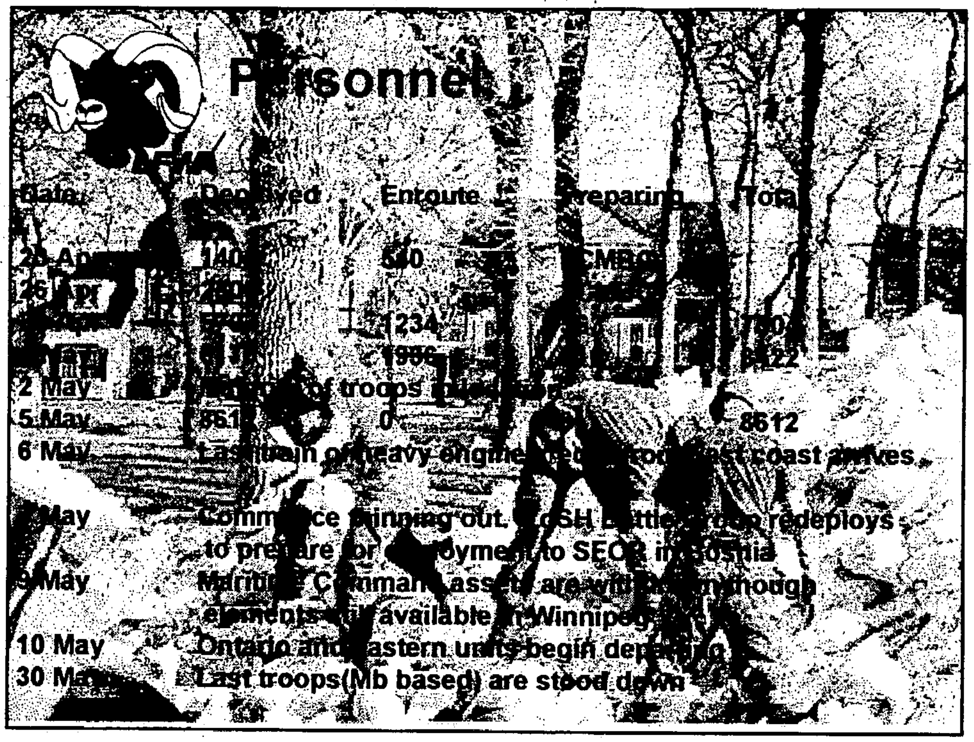
Sequence of Events

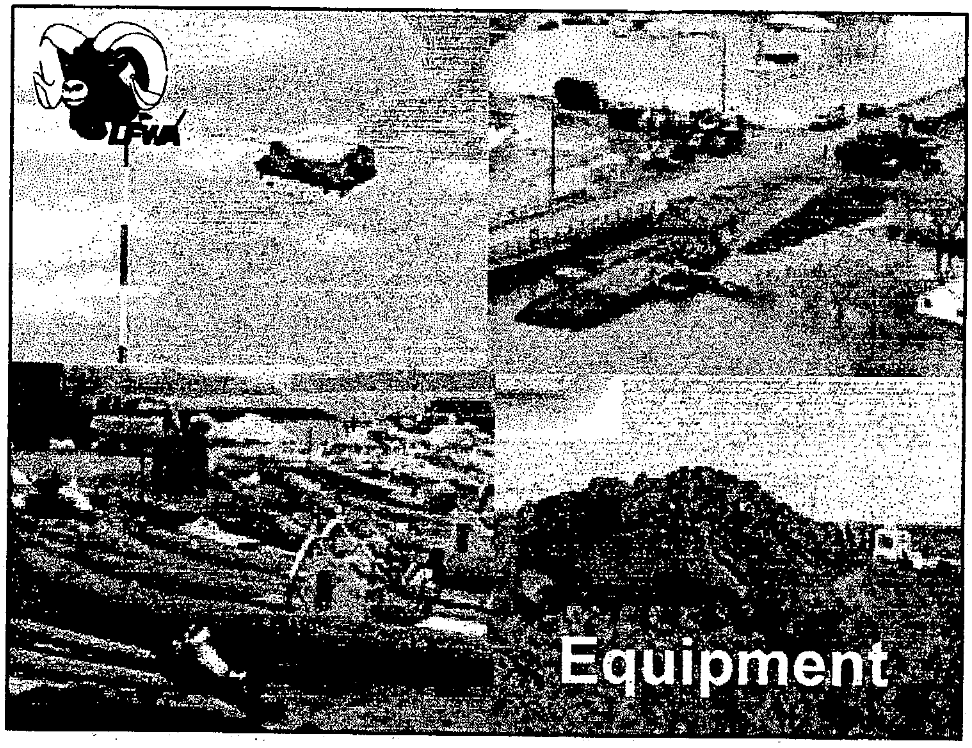
Feb	Dom Ops attends Interagency Emergency Coordination Committee meetings
3/4 Mar-	NDHQ warning order/LFWA generic flood plan
11 Apr -	Units are identified for probable tasks
14 Apr -	Flood Contingency Plan meeting in Winnipeg
15 Apr -	Units from Alberta start to preposition in Shilo
16 Apr -	LFWA prepares Min Axworthy for national press conference in Winnipeg
17 Apr -	First helicopter enroute
19 Apr -	Province signs Request for Assistance 21 to 24 Apr
20 Apr -	2 PPCLI starts tasks in St Adolphe
22 Apr -	1 CER tasked
23 Apr -	LFCA and SQFT IRU vanguards directed to move
26 Apr -	LFWA requests 1 Cdn Div HQ and 2 CMBG(+)
29 Apr -	JFHQ assumes control from LFWA HQ
30 Apr -	2PPCLI back to garrison to do personal flood preparation

Sequence of Events

2 May -	Majority of troops in location
7 May -	LdSH(RC) Battle Group departs to prepare for deployment to Bosnia
10 May -	2 R22eR departs, Maritime elements start departing
12 May -	1 RCR departs
23 May -	Primarily Engineer assets remain
30 May -	JTFHQ shuts down, for us the mission ends.



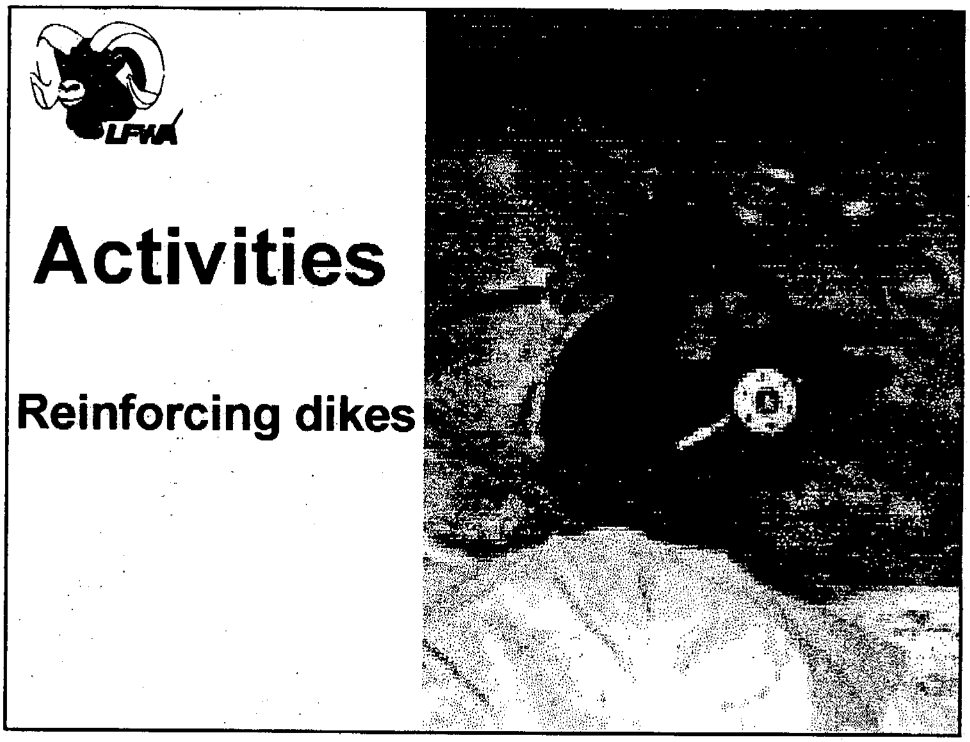

Personnel
LFWA
Entroute
1234
8612
2 May
5 May
0
6 May
10 May
30 May
Last troops(Mb based) are stood down

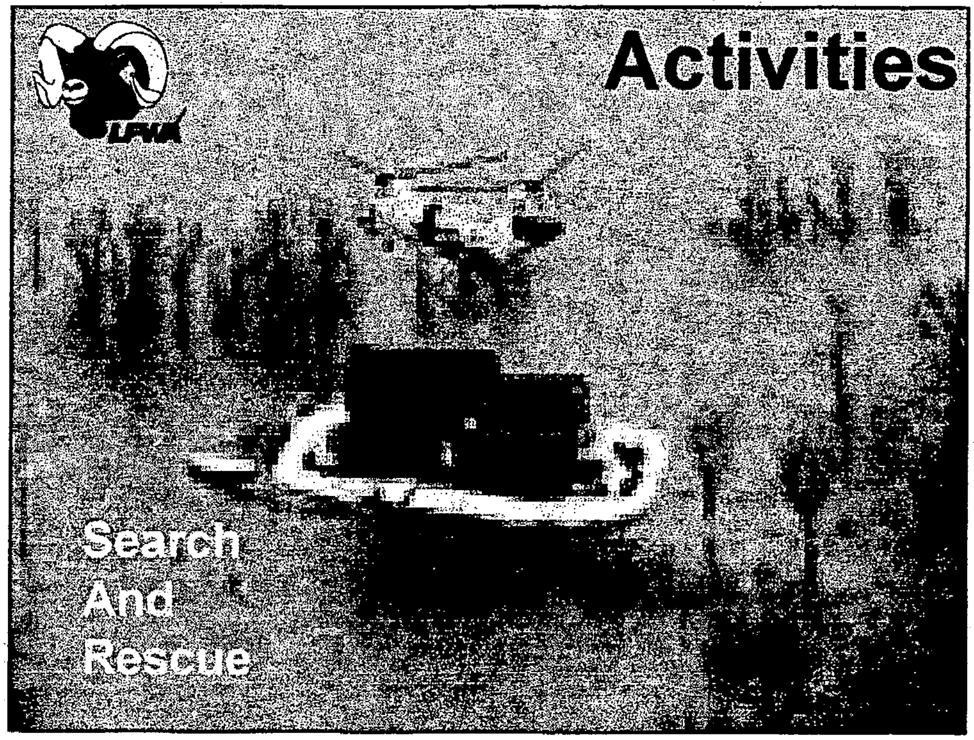

LFWA
Equipment

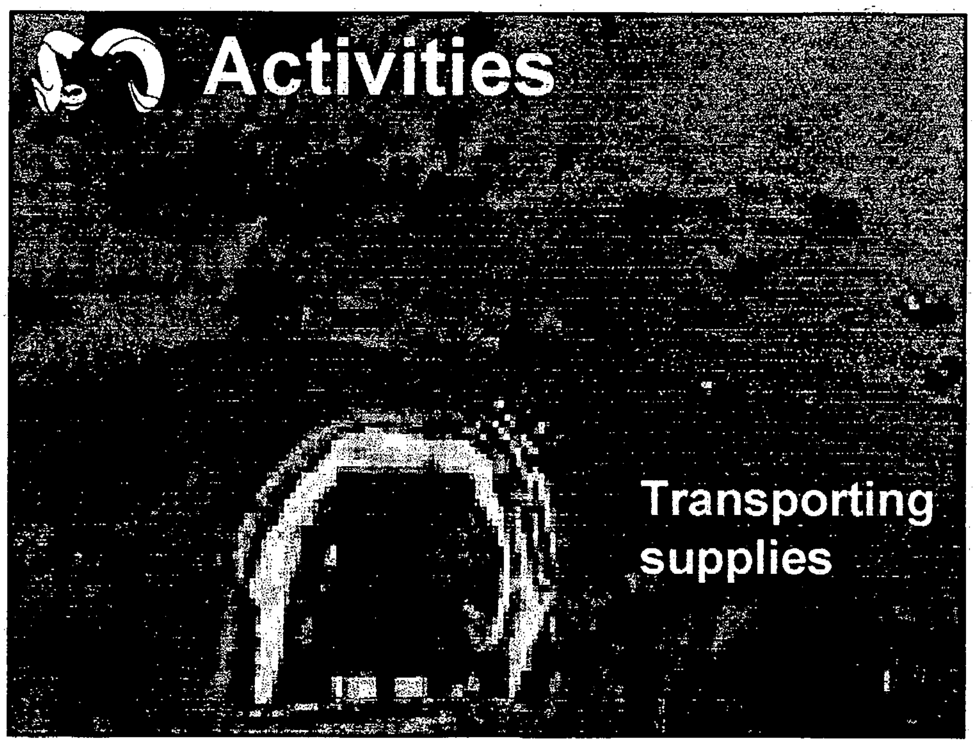

Activities
Sandbagging


LFWA
Activities
Flood awareness briefings

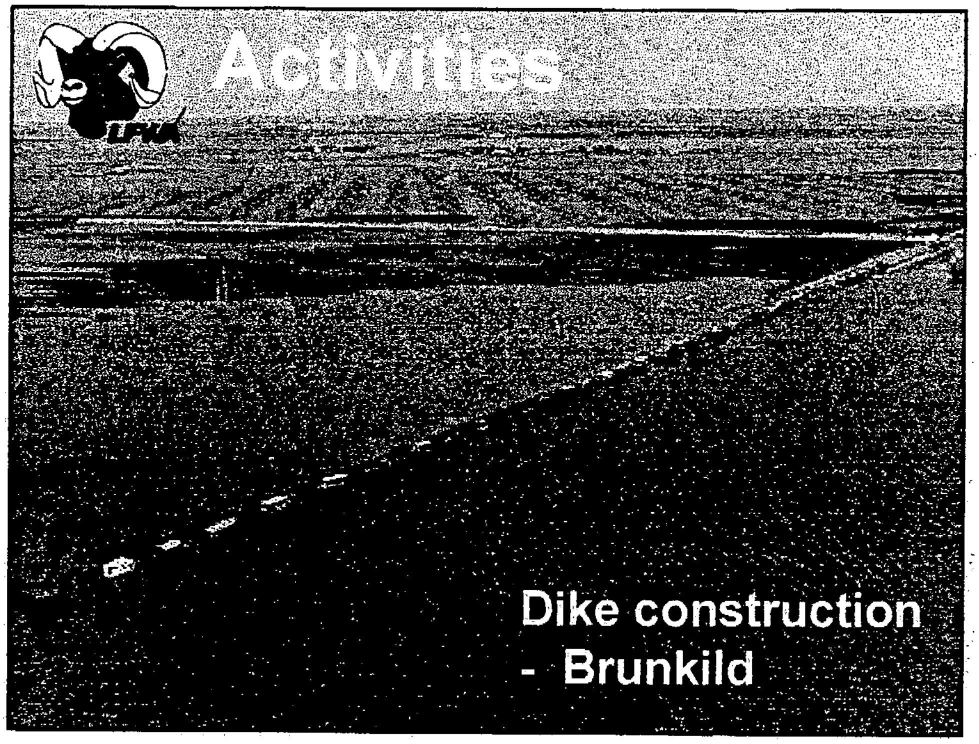

Activitie
Patrolling dikes


LFWA
Activities
Reinforcing dikes

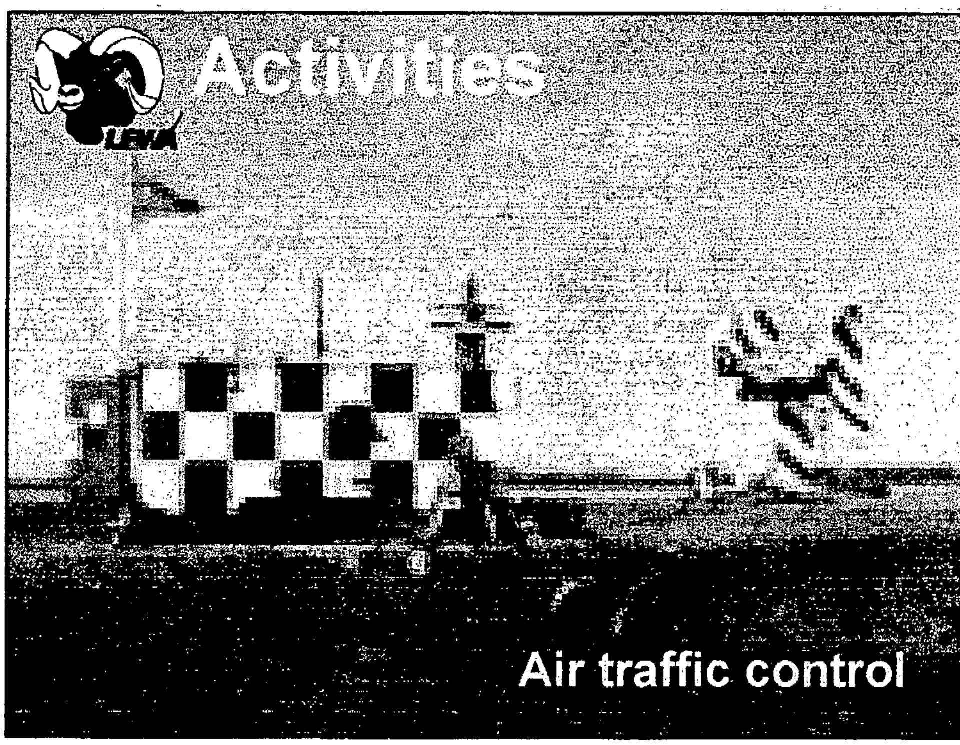

Activities
Search
And
Rescue

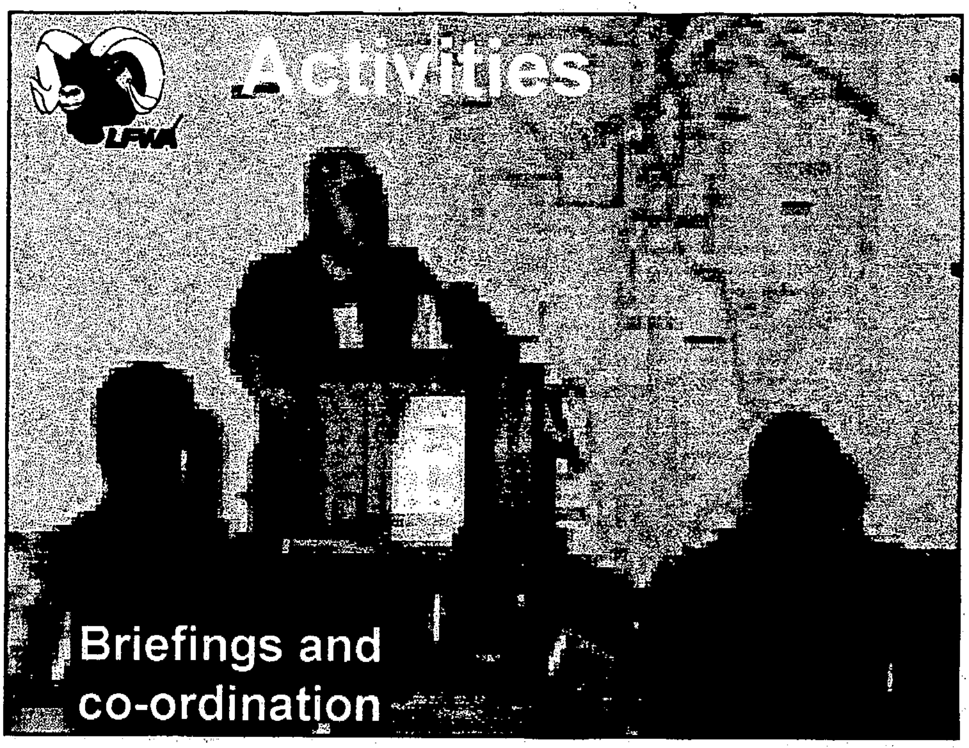

Activities
Transporting
supplies

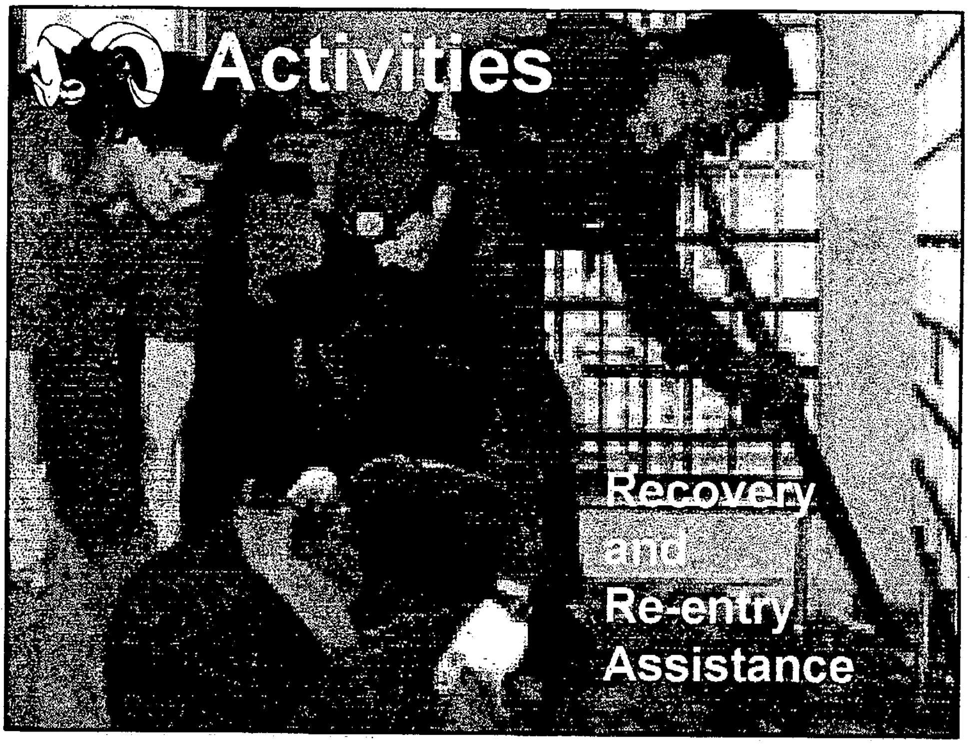

Activities
security patrols
with police agencies

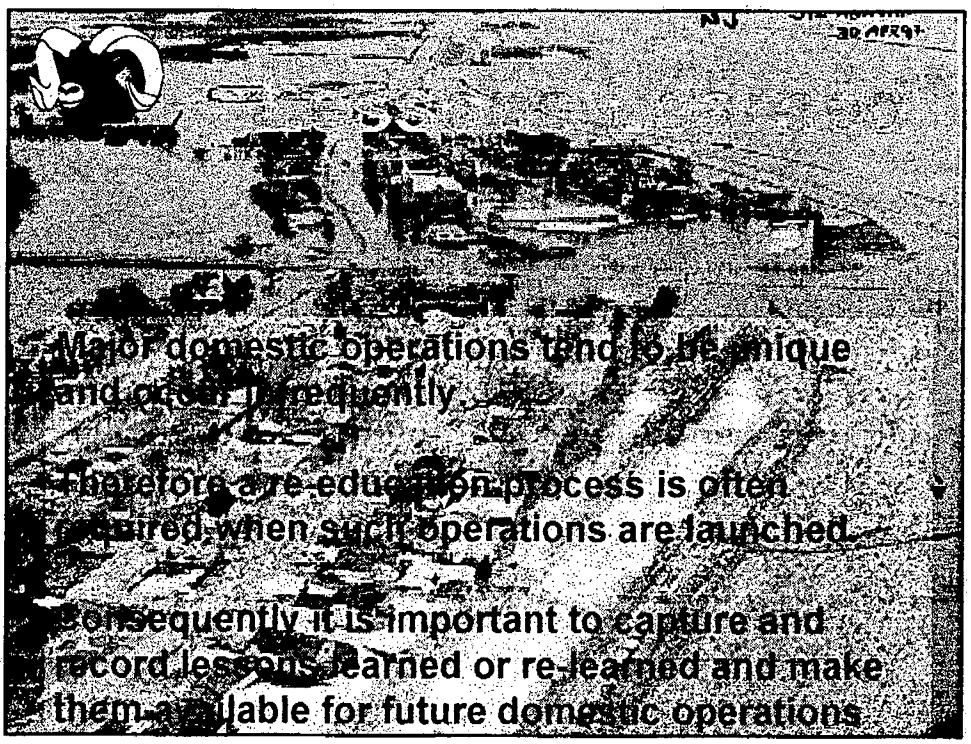

Activities
Dike construction
- Brunkild

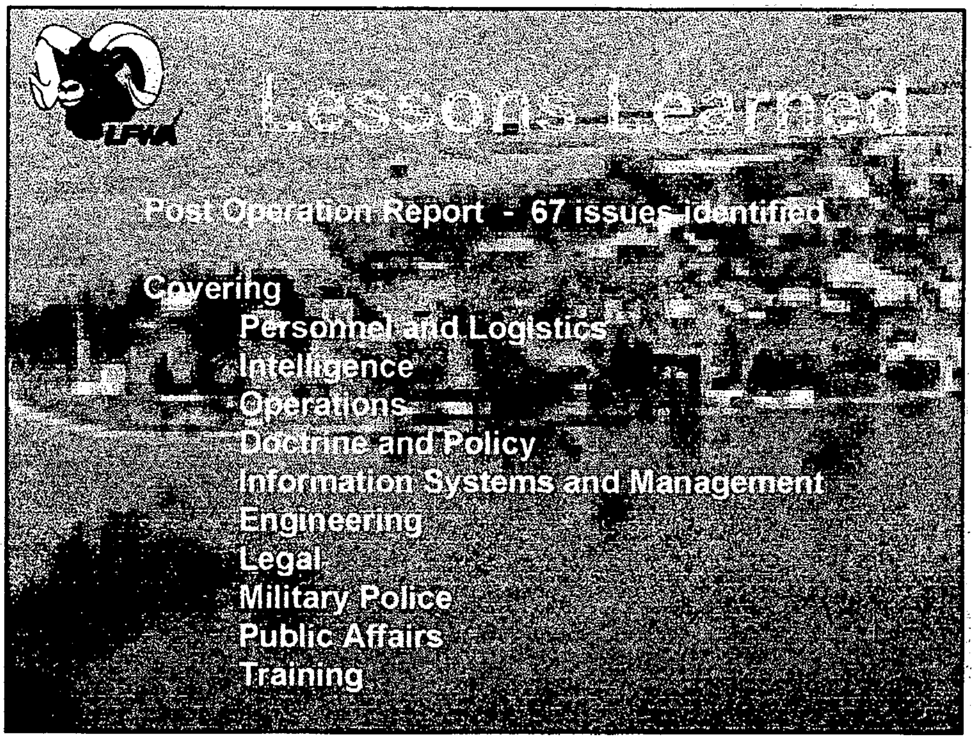

Activities
personnel

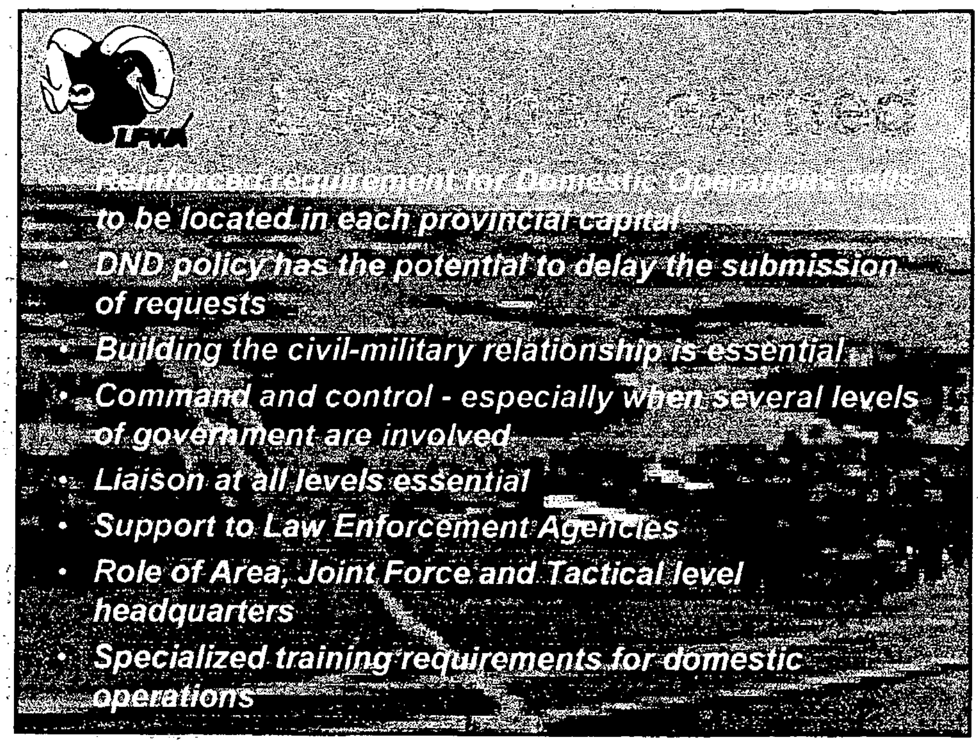

Activities
Air traffic control


Activities
Briefings and
co-ordination


Activities
Recovery
and
Re-entry
Assistance


Major domestic operations tend to be unique and occur infrequently
Therefore a re-education process is often required when such operations are launched.
Consequently it is important to capture and record lessons learned or re-learned and make them available for future domestic operations

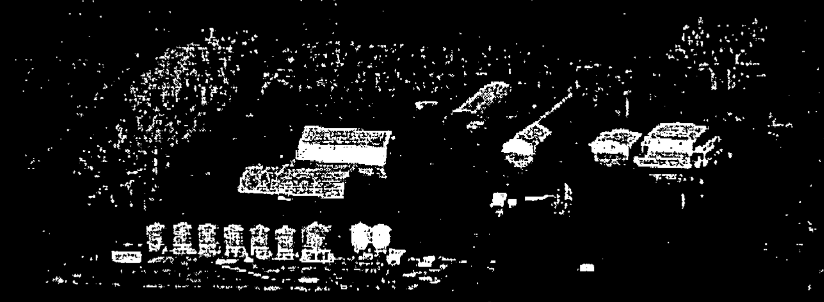

LFWA
Lessons Learned
Post Operation Report - 67 issues identified
Covering
Personnel and Logistics
Intelligence
Operations
Doctrine and Policy
Information Systems and Management
Engineering
Legal
Military Police
Public Affairs
Training


Reinforced requirement for Domestic Operations cells to be located in each provincial capital
• DND policy has the potential to delay the submission of requests
• Building the civil-military relationship is essential
• Command and control - especially when several levels of government are involved
• Liaison at all levels essential
• Support to Law Enforcement Agencies
• Role of Area, Joint Force and Tactical level headquarters
• Specialized training requirements for domestic operations


... and we leave you
with all the paperwork!!


ARMY IN THE WEST
ON GUARD FOR THEE

Damage Assessment

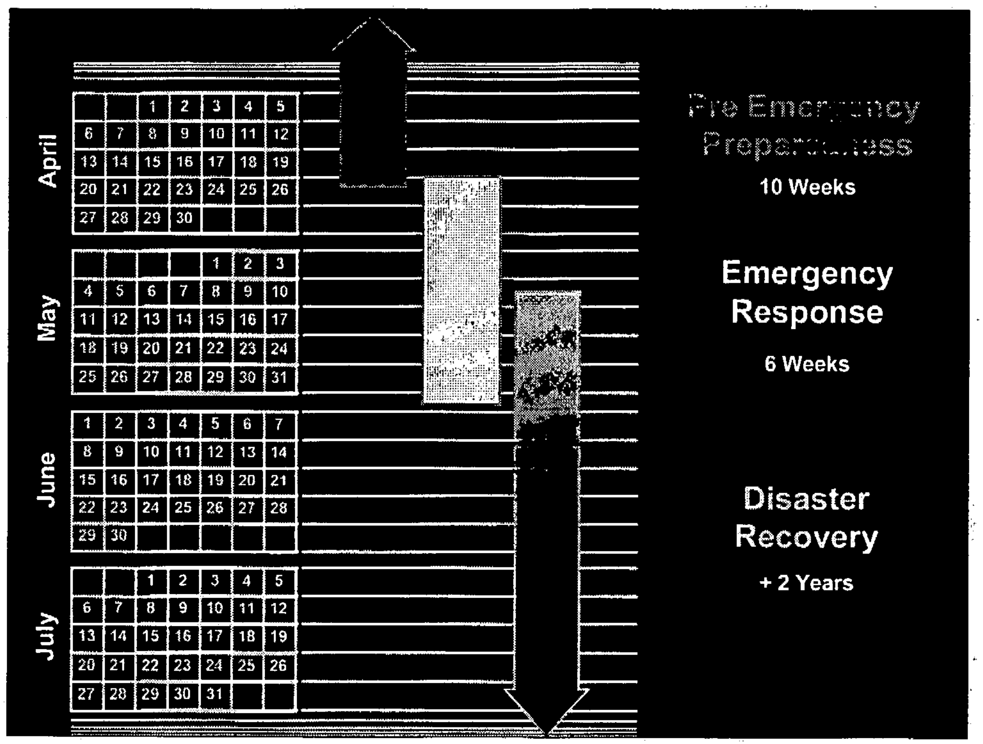


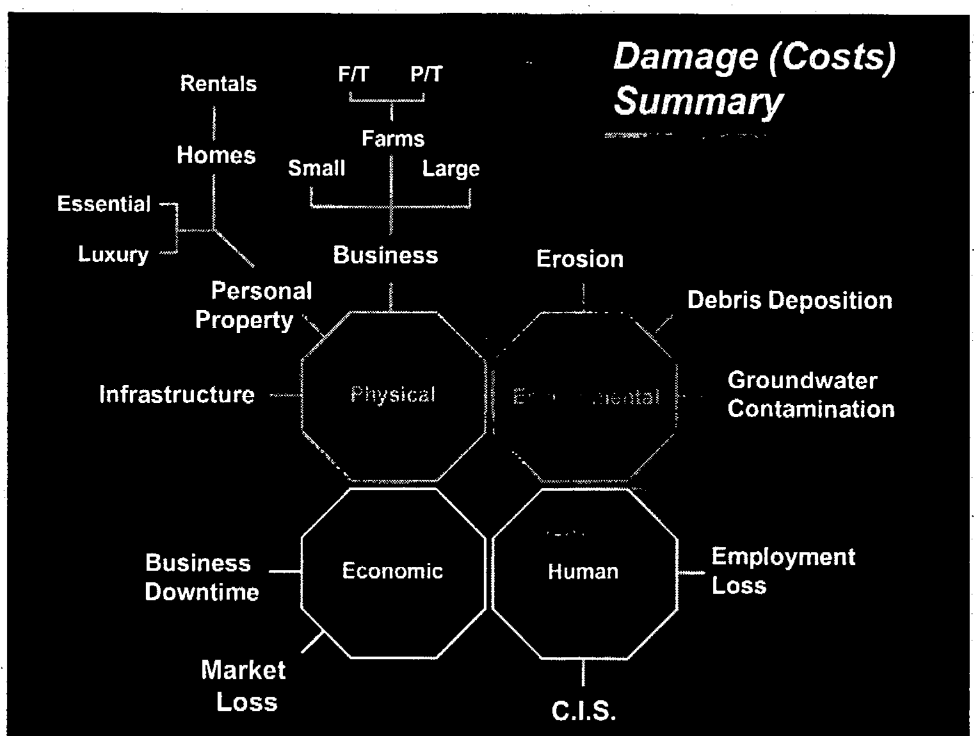
Manitoba EMO

CWRA ACRH

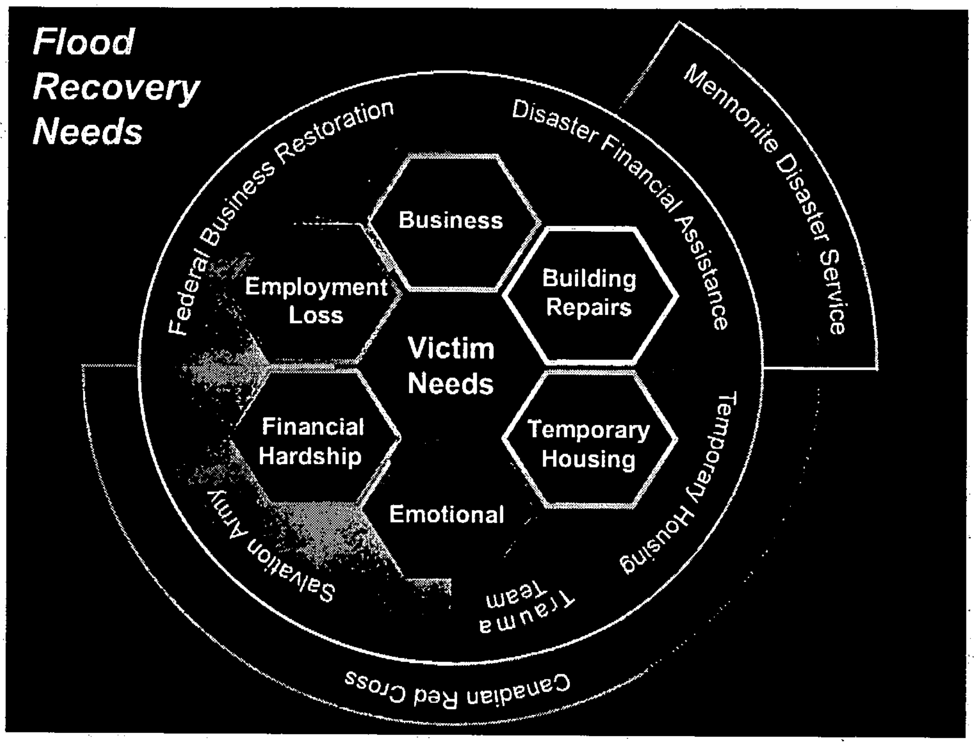
Canadian Water Resources Association

Association Canadienne des Ressources Hydriques





Critical Incident Stress



Damage Assessment Restraints

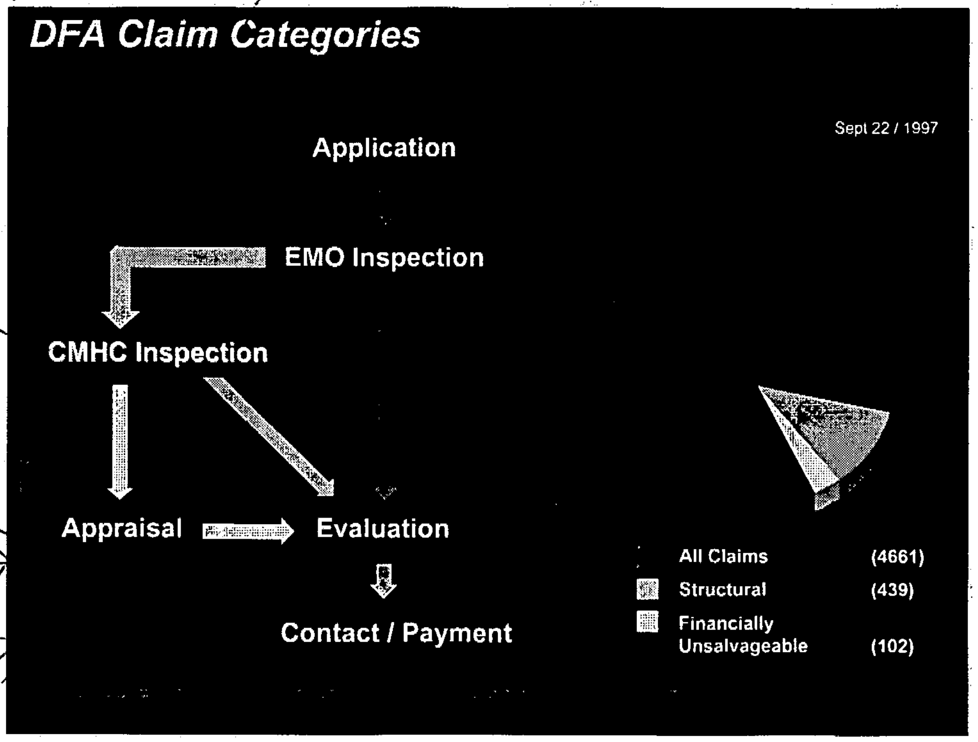
- Mandate
- Program Coverage
  - Eligibility
- Program Nature
- Recovery Time

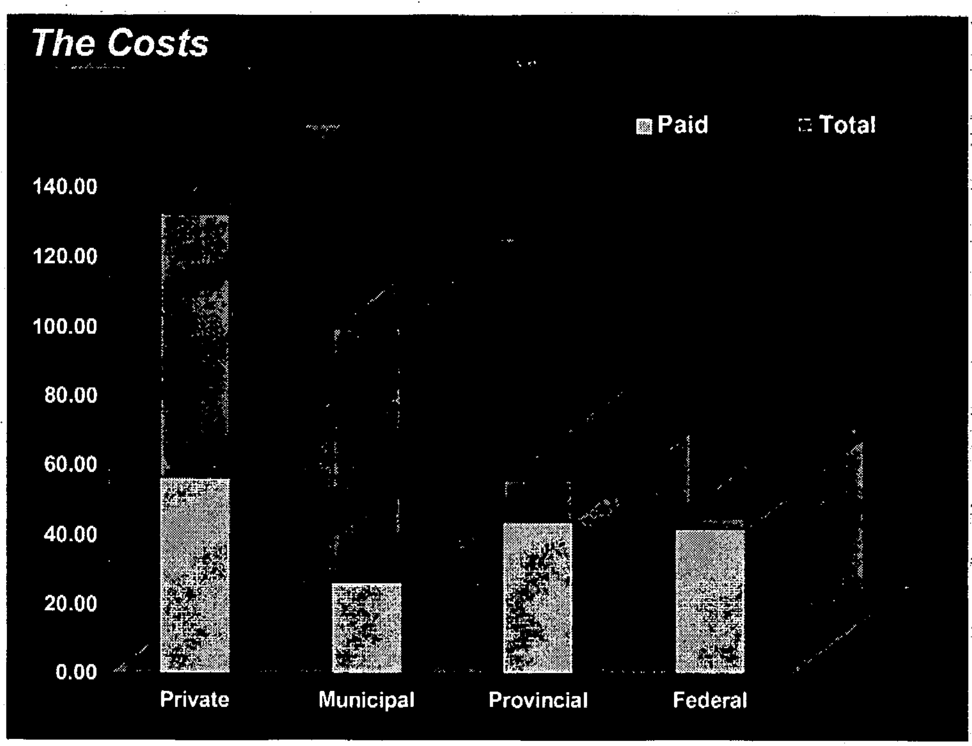
Blue Yellow Black

White text

Black

Blue box





ENVIRONMENTAL IMPACTS

Dwight Williamson, Colin Hughes, and Edward Sorba
Water Quality Management Section
Manitoba Environment
123 Main Street, Suite 160
Winnipeg MB R3C 1A6

Summary

The 1997 flood of the Red River was the largest recorded during the last century, and was surpassed by only two previous events recorded during the last 170 years. The largest flood occurred in 1826, devastating the Red River Settlement, presently called the City of Winnipeg. As soon as it was recognized that a flood of relative enormous magnitude could potentially affect the Red River valley in 1997, measures were taken in cooperation with other local, provincial, and federal governments, and most importantly, with product associations within the basin, to ensure that home, agricultural, and petrochemical products were safeguarded to the extent possible. As well, an intensive water quality monitoring program was initiated for two purposes. First, water treatment facilities protected within ring-diked communities in the basin expected to continue to operate throughout the flood and needed some assurance that raw water quality was not sufficiently impacted to affect treatment capabilities. Water quality could be adversely impacted during flood events from various pollutant sources such as dead animals, agricultural and municipal lagoons, stored agricultural and petrochemical products, plus others. Second, water quality measurements at some sites on the Red River extend to the mid-1960s. The flood of 1997 represented an opportunity to enhance this data-set and to gain a better understanding of water quality changes that occur during unique, high-flow events.

As expected, total suspended solids increased substantially in the Red River due to the entrainment of sediment particles. Inundated farmstead dugouts required remedial treatment to reduce sediment concentrations. No major impacts have yet been identified in the Red River or downstream in Lake Winnipeg from the large sediment load. However, Fisheries and Oceans Canada, in conjunction with other agencies, contemplates undertaking additional work, particularly to characterize sediment and associated pollutant contributions to Lake Winnipeg.

Fecal coliform bacteria densities, a specific indicator associated with gastrointestinal illness, increased somewhat during the climbing limb of the hydrograph, then declined to levels only slightly above normal spring-time densities. Upstream from the City of Winnipeg, fecal coliform densities exceeded the commonly-used recreational water quality objective of 200 organisms/100 mL briefly, then declined to normal levels. Downstream from the City of Winnipeg, fecal coliform densities exceeded the recreational water quality guidelines, but did not differ significantly from those normally measured in this reach. Densities of the general or non-specific fecal streptococci group appeared higher than normal at Emerson near the United States / Canada boundary in samples collected by Environment Canada. This is normally expected during flood events since some bacteria measured in the fecal streptococci test are native to soils and plants. These findings were similar to those reported by the United States Geological Society (US GS) during similar work conducted cooperatively with the Minnesota Pollution Control Agency and North Dakota Department of Health. Although the observed bacteria densities were not unusual for the Red River and many other prairie streams draining populated regions, levels were sufficient to significantly contaminate groundwater in localized areas south-east of the City of Winnipeg. Large volumes of flood waters entered the carbonate aquifer through improperly sealed wells. Intensive bacterial monitoring of

Lake Winnipeg beaches during the summer of 1997 indicated no significant differences in fecal coliform densities relative to previous years.

Contrary to early predictions, only trace concentrations of a few organics were detected using conventional analytical techniques. These included 2,4-D, triallate, trifluralin, and lindane. Concentrations were all less than Guidelines for Canadian Drinking Water Quality, and were not significantly different than concentrations observed routinely in the past. For example, 2,4-D is detected in between 20% and 30% of all samples collected in the prairie ecozone of Manitoba and therefore was not unexpected in spring flood waters. In addition, the US GS reported atrazine, di-ethylatrazine, and metolachlor in Minnesota and North Dakota. Two materials, however, were detected that were unexpected. First, pentachlorophenol or one of its breakdown products was detected on a number of occasions. Pentachlorophenol was thought to arise from the inundation of treated railway ties, poles, and bridge works. Concentrations were considerably less than the Guidelines for Canadian Drinking Water Quality. Second, heptachlor, dieldrin, and DDT were detected in samples collected by Environment Canada near the United States / Canada boundary. These materials either have not been detected in the past or detected very infrequently (<1%), are not registered for general use in the United States or Canada, and therefore were not expected. These materials are highly persistent. Trace residuals may have remained on Red River valley soils following their use several decades ago and were transported during the spring flood with sediment particles. Despite observing visible oil films or sheens on the surface of the Red River immediate upstream of the City of Winnipeg, no hydrocarbons were detected in the water column (total hydrocarbons, ortho-, para-, and meta-toluene, benzene, or ethyl benzene). Similar analyses conducted in Minnesota and North Dakota and reported by the US GS revealed trace concentrations of several volatile organic compounds associated with petroleum products (alkylbenzenes, naphthalene, chlorinated solvents, me
thyl ethyl ketone, and acetone).

Total phosphorus concentrations remained elevated during the peak flow periods, while nitrate-nitrite levels declined steadily during the course of the flood. Dissolved oxygen concentrations remained well within acceptable levels throughout the flood.

In general, impacts to water quality were not as significant as originally expected. Despite numerous sources of pollutants available for transport to the Red River during the 1997 flood event, impacts were minimized for two main reasons. First, many sources of pollutants were safeguarded through advance planning immediately prior to the flood, and second, the very large volume of quite clean snow-melt water diluted remaining materials to relatively low concentrations. Improvements, however, can be made in several sectors to assist with minimizing impacts from future floods.

REHABILITATION OF MICROBIOLOGICALLY CONTAMINATED GROUNDWATER RESULTING FROM THE 1997 RED RIVER FLOOD

Grande Pointe Case Study

Rick M. Lemoine, P. Geol.
Manitoba Environment

and

Jennifer L. Corkery
Queens University
Department of Geological Engineering

ABSTRACT

The 1997 Red River flood created an unprecedented impact on the groundwater resource of some Manitoba communities, resulting from the influx of flood water into the Upper Carbonate Aquifer. The result was microbiological contamination (total coliform and fecal coliform bacteria) of the drinking water source for a number of flooded communities. This presentation focuses on the contamination of the local aquifer beneath the community of Grande Pointe in the Rural Municipality of Ritchot, where the groundwater was rendered unsuitable for human consumption for the entire summer season of 1997.

In April of 1997, microbiological water quality test results being forwarded to Manitoba Environment, indicated significantly elevated total coliform and fecal coliform, specifically E. coli bacteria counts in samples of groundwater being submitted by Grande Pointe residents. In addition, Manitoba Environment staff had visual confirmation that a number of abandoned water wells in the community, were inundated by water during the flooding stage. There was a strong possibility, therefore, that the poor microbiological water quality of the groundwater samples tested, was due to flood water entering the local aquifer zone via these derelict water wells.

In response to this situation, detailed community-wide groundwater sampling and analysis was conducted by Manitoba Environment. Reconnaissance field work, aimed at the location of abandoned and operating domestic wells, was also conducted within the community. A total of 16 abandoned wells were found scattered throughout all areas of the Grande Pointe community. In addition, a number of other "problem wells", such as pit-type wells, well casings damaged by boats during the flood, and wells left outside of constructed sandbag dikes, were also found.

With the exception of a small area in the southernmost Grande Pointe area, sample results of groundwater from all across the community indicated some degree of microbiological impact. Total coliform bacteria counts detected in groundwater samples ranged from 1 to > 2,000 counts/100 ml, with E. coli counts ranging from 0 to 95 counts/100 ml.

Field sampling and analyses for groundwater parameters including electrical conductivity (EC), total dissolved solids (TDS), and temperature, yielded data which indicated that wells and local aquifer zones in some regions of the community had been inundated by surface flood waters to greater degrees than other areas. In general, field groundwater quality testing results (i.e. EC, TDS, temperature) indicative of flood water impact, correlated strongly with groundwater zones of high microbiological contamination.

Upon assessment of the local hydrogeological conditions and delineation of the relative extent and degree of severity of the groundwater impact, remedial actions were designed and implemented. The premise of the corrective actions for groundwater quality was to "reverse" the impact process and enhance "natural flushing" of impacted groundwater, by waste-pumping "contaminated water" from the local aquifer zones via the existing wells. Wasting of water was conducted by installing dedicated submersible pumps or compressed air lines into well casings, depending upon individual well yields, and water was pumped or air-lifted from the wells. Waste water was monitored for EC, TDS, and temperature in order to determine when relatively "fresh" groundwater was being pumped from the well.

Disinfection (chlorination) of the wells/local aquifer zones was then conducted. Disinfection procedures consisted of injecting 1,300 to 2,700 liters (300 to 600 Imp. gallons) of chlorine solution (using 12.5% sodium hypochlorite solution and unimpacted groundwater from a local well), with chlorine concentrations ranging from 400 to 1,000 mg/l of chlorine. In addition, pumps, hoses, and other well components were also cleaned, disinfected, or replaced, as necessary.

Microbiological water quality from domestic wells was then monitored over time on a well-by-well and local residential area basis, in order to determine the effectiveness of the remedial actions conducted. Where necessary, the treatment procedures were repeated, with variations to pumping rates, volumes, chlorine solution volumes and strengths made, as required in order to attain consistently low microbial counts in groundwater samples. In some cases, where the well structure itself was the problem and not the groundwater quality, new water wells were installed in order to provide potable water to residences.

The final stage of the entire groundwater rehabilitation program, in addition to long-term monitoring of water quality, was to implement well improvement and proper well abandonment actions. Domestic wells of pit-type construction were improved by converting them to pitless design. In the majority of cases, these actions were well accommodated as residents were also raising the elevations of their housing foundations. In the case of abandoned wells, the well-owners were offered the opportunity to keep the wells so long as proper maintenance and sealing of the wells was conducted. Where owners did not wish to maintain a well, or where no owner could be assigned, proper well sealing actions were taken by Manitoba Environment in order to protect the groundwater resource from surface-borne contaminant sources.

The 1997 flooding in the Grande Pointe region resulted in severe impact on the local groundwater quality via the introduction of surface water through derelict water wells. Despite the intensive and successful remedial actions conducted by Manitoba Environment, residents of Grande Pointe were forced to obtain drinking water from alternative sources for up to 3 months following the recession of the flood water. If left to natural mechanisms for reviving the groundwater to drinking water quality status, Grande Pointe residents would have had to endure a longer period of time without the use of the local groundwater.

REHABILITATION OF MICROBIOLOGICAL CONTAMINATED GROUNDWATER FROM THE 1997 RED RIVER FLOOD

GRANDE POINTE CASE STUDY

PRESENTATION OUTLINE

- Cause/Problem
- Impact
- Investigations
- Remedial Measures
- Results
- Conclusions
- Question Period

STUDY TEAM

- **Manitoba Environment**
- **MEMO**
- **Water Resources**
- **RM of Ritchot**
- **City of Winnipeg**
- **Well Contractors**
- **EnviroTest Labs**
- **J. Oosterveen**

- Jennifer Corkery
- Michelle Boulet
- Mandy Whalen
- Lisbeth Liebgott

Thanks to the residents of the affected areas.

THE IMPACT

The loss of the local groundwater resource as a source of potable water to approximately 150 homes.

THE PROBLEM

Influx of floodwater rich in nutrients and debris leading to favourable conditions for growth and migration of bacteria in the aquifer.

INVESTIGATIONS

- Community-wide water sampling and microbiological analyses.
- Reconnaisance of all domestic wells in the community.
- Location of abandoned wells in community.

REMEDIAL MEASURES

- General -"Reverse" the impact process.
- Waste contaminated water from wells/ local aquifer zone to non-impacted groundwater, and disinfect.
- Water quality sampling and analyses (field and laboratory).
- Re-construct "poorly constructed" wells.
- Drill and install new wells.

GROUNDWATER BACTERIA COUNTS

MAY 1997

Range: 0 - > 2,000

Mean (n= 144): 195

38 samples (26%): 0 - 0

58 at (40%) at > 200

E. Coli range: 0 - 95

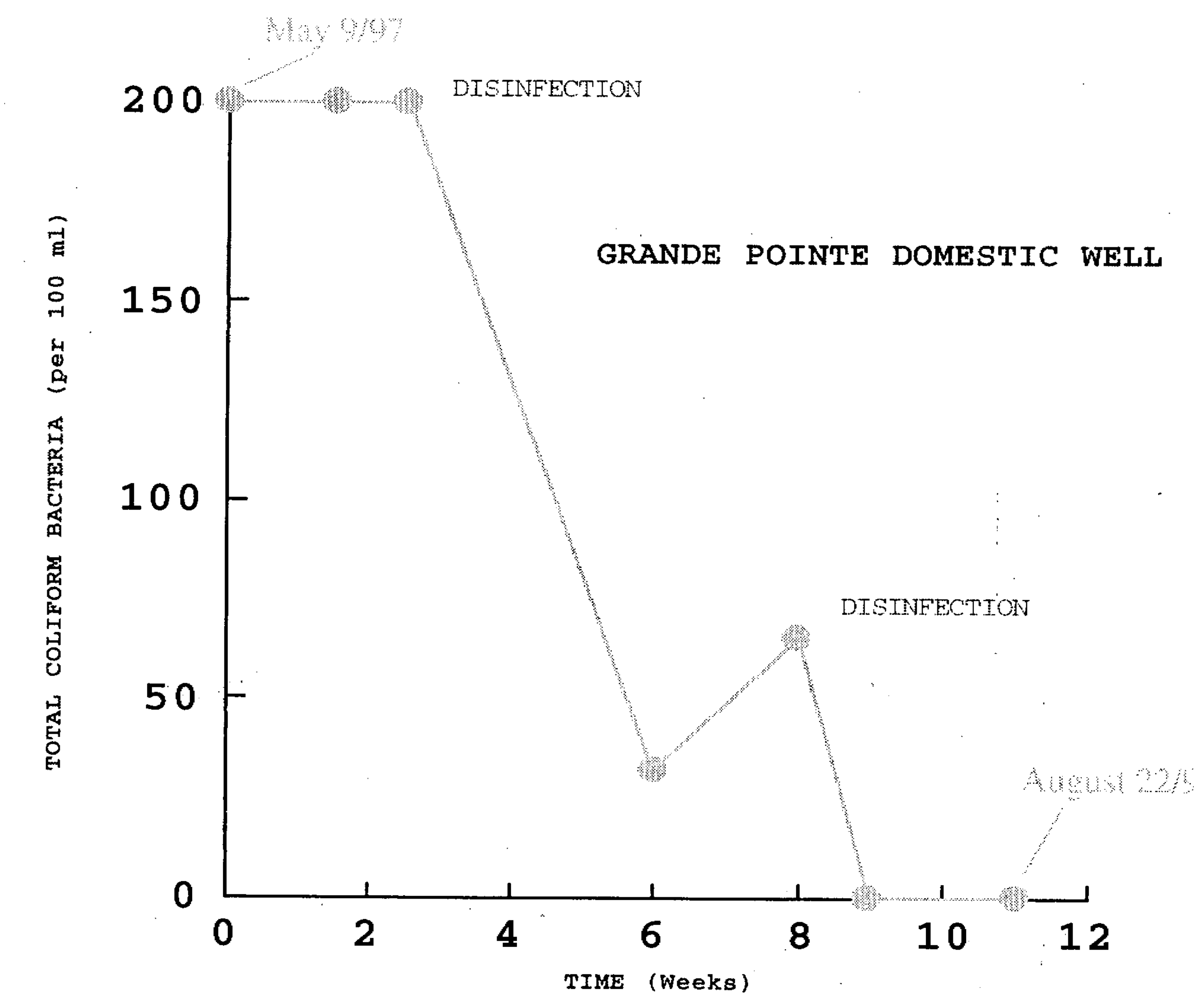
47 positive E. Coli.

JULY 1997 (Post Treatment)

Range: 0 - >200

Mean (n= 130): 27

Three positive E.Coli samples (range 1-4).


GRANDE POINTE DOMESTIC WELL
May 9/97
DISINFECTION
DISINFECTION
August 22/5
TOTAL COLIFORM BACTERIA (per 100 ml)
200
150
100
50
0
0
2
4
6
8
10
12
TIME (Weeks)

CONCLUSIONS

- “Natural” mortality period for microorgansims in the aquifer exceeded what is “normally expected”.
- In Grande Pointe, this is due to hydrogeological conditions which allowed bacteria to thrive beyond the “normal”.
- Intervention was required for “benefit”.

SUMMARY

- 1997 flood produced an unprecidented effect on the groundwater quality of Red River valley residents for months.
- Large volumes of flood water were intorduced into the UCA via improperly abandoned and poorly constructed wells.
- Rehabilitation program provided potability to residents beyond “natural capacity”.

Coagulation Treatments for Flooded Dugouts

AUTHORS: Robert Butler, *PFRA Winnipeg.*, Darrell Corkal, *PFRA Saskatoon*

Abstract:
In-reservoir dugout coagulation was applied to flooded dugouts in Manitoba after the 1997 Red River flood. Chemicals for the treatments were funded by Manitoba Emergency Management Organization, and equipment staff were provide by PFRA. The treatments restored or improved dugout water quality to levels that might otherwise have taken years for natural processes to achieve. This scale of work also resulted in gaining knowledge equivalent to about five years worth of applied research, and will lead to a better understanding of using dugout coagulation as a management tool in the future. Dugout coagulation costs will range from $260 to $650 for typical two to five million Litre dugouts if producers provide their own equipment, labour and chemical shipping.

In the Red River Valley west of the Red River, many producers rely on dugouts (farm ponds) as their sole source of water for domestic and production needs (primarily livestock watering). The 1997 Red River Flood contaminated many of these water supplies. According to the producers, they had never experienced such poor water quality. Increases in microbial contamination, suspended sediment, turbidity, and plant nutrients such as phosphorus occurred from the flood water. All of these factors could contribute to future problems such as increased weed and algae growth.

Dugout coagulation technology was recently developed by PFRA and the Saskatchewan Research Council under the Saskatchewan Surface Water Quality Initiative. In Saskatchewan, in-reservoir coagulation treatments were adapted to farm ponds to reduce phosphorus and dissolved organic carbon. Treated dugouts were less susceptible to algae growth, safer to use with in-house treatment, and had significantly improved clarity. Reductions of organic matter in the reservoir resulted in less formation of carcinogenic trihalomethanes, a by-product that occurs in water disinfected with chlorine.

Farm ponds contaminated by floodwaters provided an opportunity for PFRA to apply coagulation technology to help people return to their homes and livelihoods as soon as possible.
The first step was to ensure that the technology could be applied under such extreme sediment loadings. The Saskatchewan Research Council in Saskatoon, performed pre-screening of dugout water samples in order to assess the potential effectiveness of the treatment and to determine optimum chemical dosage using liquid aluminum sulphate. Effective treatment was predicted with coagulation doses in the range of 10 to 25 mg/L (as Al). Limiting factors were alkalinity and pH, as post-treatment alkalinity could not be lowered below 20 mg/L and pH could not be lowered below about 6.0. On-site pail tests (a crude version of a jar test) were developed to assist in on-site dosage prediction.

The actual pond treatment process was not complicated. It took about 2 to 4 hours to treat a dugout (ranging from 2 to 30 million Litres). One to three small motorboats were moored in the dugout, and each boat motor was operated to stir the dugout for about 30 minutes before adding chemical. Liquid aluminum sulphate was then slowly pumped from shore into the dugout at the churning propeller to simulate a flash mix. The chemical addition usually ranged from 30 to 120 minutes and the dugout mixing continued for an additional 60 minutes after chemical addition (simulating a slow mix, and allowing for particle agglomeration as the coagulant collided with dissolved and suspended matter in the water).

In most cases, remarkable clearing of the water occurred by the time the PFRA crews had packed up the equipment to move to the next site, with turbidity reductions from 90 Turbidity Units to 20 Turbidity Units or less.

Clarity improvements, however, are not the most important measure of success for pond coagulation. This was evident when water quality was measured in late August. Some treated sites experienced a rebound in turbidity levels, yet remained mostly free of blue-green algae (water with blue-green algae can be toxic to humans or animals). The flood water was believed to have increased the ratio of Phosphorus to Nitrogen in the dugout water, a condition which would favour increased blue-green algae growth. By removing phosphorus and organic matter, coagulation treatments counteracted this negative effect.

Coagulation treatments are a temporary measure that can result in improved water quality for periods as long as two to ten months. However, if poor quality water or influent sediment enters the dugout from runoff after treatment, water quality will deteriorate. For some of the flood-affected dugouts, water quality reverted because the sediment was disturbed by human or animal activity (eg. Using the dugout as a swimming hole); in other cases, with no grassed zones new inflow during rains washed phosphorus-rich sediment into the dugout, negating some of the benefits of treatment. Grassed buffer zones (30 m minimum) are recommended for all water bodies together with land management practises which prevent nutrient inputs (eg. fencing to prevent animal access, and, preventing fertilizer or pesticide transfer from land to water, etc.). Some sites may have reverted due to lack of aeration, allowing for nutrient recycling from the bottom sediments to negate the benefits of treatment.

Coagulation with aluminum sulphate usually results in increases of aluminum and sulphate. These must be managed to ensure that the levels do not become excessive for the reservoir, or for drinking water needs. Short-term spikes in dugout aluminum levels are manageable with an additional in-house polishing treatment device such as a reverse osmosis membrane or distiller if drinking and cooking water is required. The levels of aluminum in the flood-affected dugouts were usually lowered by the treatments as aluminum-rich suspended sediment settled to the dugout bottom.

Most producers were pleased with dugout coagulation treatments, which provided marked improvement in water quality. One producer had been hauling over 6000 gallons of water each day for his hog operations. PFRA was able to improve his dugout water quality before the producer was able to restore the rest of his water system. Another producer was replacing cartridge filters every one to two days in his filtration system. After the dugout coagulation treatment, the change-out frequency for the cartridge filters increased to more than 20 days.

In addition to the immediate flood relief benefits following the 1997 Red River Flood Dugout Coagulation Program, PFRA's Water Quality Unit continues to compile data from this work to determine whether or not dugout coagulation may be an effective and routine management strategy. Treatments would likely be required each spring (after runoff and settling). During treatment water quality testing and follow-up would be necessary to track aluminum and sulphate levels, especially when repeated applications are required. If producers were to provide their own labour, equipment and shipping, the costs to treat a dugout may be reduced to about $130 for each one (1) million Litres of water to be treated.

Acknowledgements: The authors wish to thank PFRA staff from Manitoba, Saskatchewan and Alberta who assisted with the flood relief, and Manitoba Emergency Management Organization who funded the coagulation chemicals. The authors wish to thank Tracy Broley and Dr. Hans Peterson of the Saskatchewan Research Council for their quick response in completing pre-screening laboratory work. Dugout coagulation technology was developed with funding from the Canada-Saskatchewan Agriculture Green Plan Agreement.

Assessment of National Weather Service Hydrologic Models and Forecasts for the Red River of the North

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INTRODUCTION

The United States weather and flood warning services program, basically for the protection of life and property, has been in place since 1890 (Stallings and Wenzel, 1995). Hydrologic forecasts have typically been provided for low lying areas in the vicinity rivers. A major step in the ability to forecast flood levels came in the 1940s when the first River Forecast Centers were placed into operation. At that time continuous run-off modeling, done by hand calculation, provided the capability to forecast the response of precipitation over a basin and relate that discharge to a stage on an established river gage. Computers came on line in the 1960s and 70s, advancing the ability to process hydrometeorologic data and preform model calculations with greater speed and accuracy. Later generations of computers in the 1980s and 90s, coupled with advanced software, greatly increased the capability to produce hydrologic forecasts. In the late 1990s, the Advanced Hydrologic Prediction System (AHPS) is being implemented with the objective to provide products that contain the relative uncertainty of hydrologic variables. Discussed will be the next level of model capabilities and the status of AHPS product formats that are operationally being produced currently for the Des Moines River Basin, in Minnesota and Iowa. In the aftermath of the "Great Flood of 1993" and the 1997 record flooding on the Red River of the North in the United States (Figure 1), the National Weather Service (NWS) is focusing attention toward improving the capability of informing emergency and water resources managers with information and forecasts that will significantly mitigate the impact of major floods and droughts.

HYDROLOGIC PROCEDURES

The thirteen River Forecast Centers (RFC) of the NWS utilize a very large software system to produce model output that is the basis for determining forecasts of discharge and stage time series. This system is called the NWS River Forecast System (NWSRFS). In the United States there are approximately 4,000 forecast points where specific hydrologic forecasts are prepared routinely.

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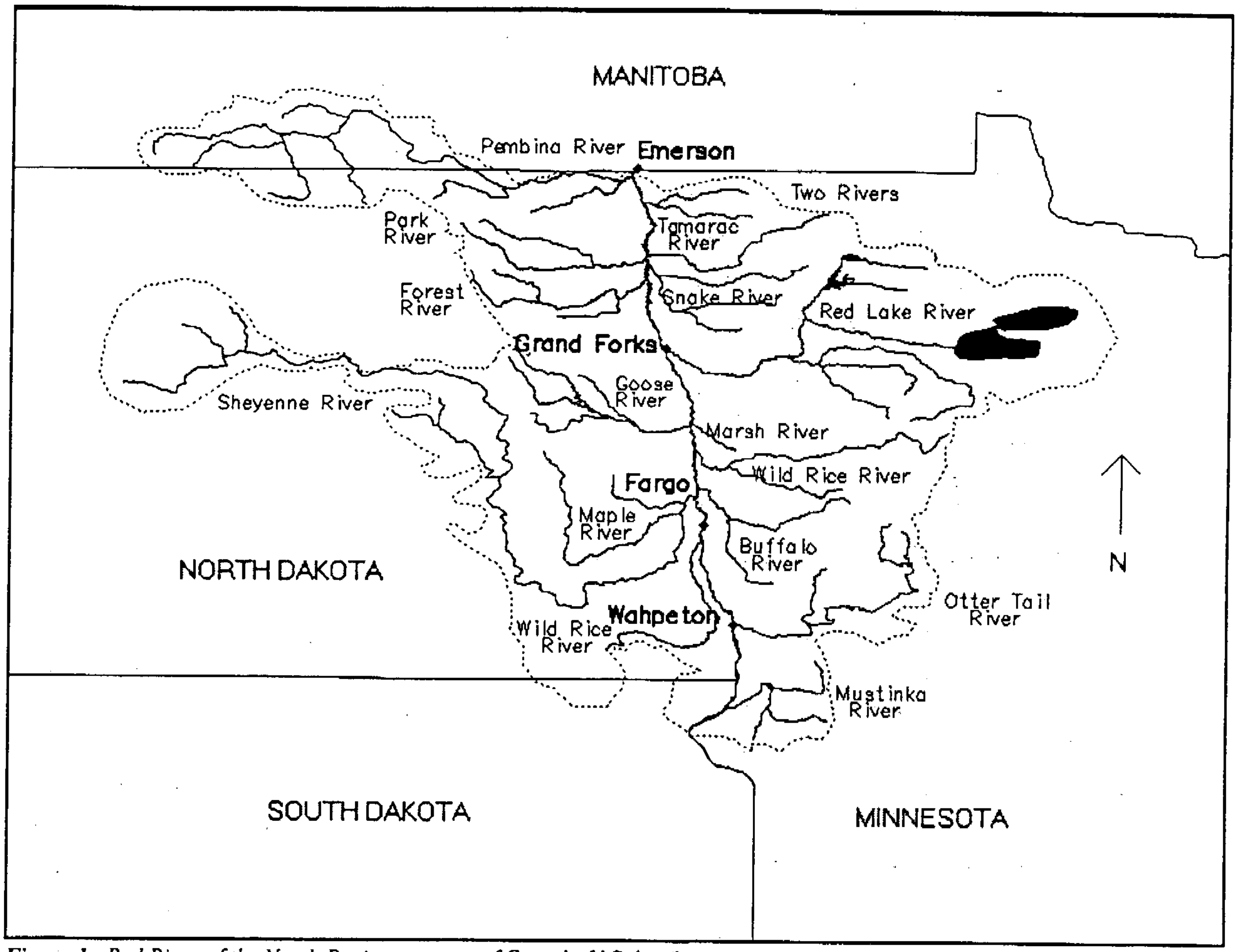


Figure 1. Red River of the North Basin upstream of Canada-U.S. border.

The flexibility of this system allows for various models to be included within the framework of the NWSRFS. For several decades the most common run-off model in use by the NWS has been the Antecedent Precipitation Index (API) technique. With the API, the assumption is that soil moisture decreases logarithmically with time when no precipitation occurs. Combined with the use of a coaxial rainfall-runoff relationship and the API, it is possible to determine runoff over a watershed. A limitation of the API model is its short term memory (approximately 30 days). The API model was used in calculating run-off response for the April 1997 Red River of the North flood event.

In the past several years the NWS has been developing and implementing a conceptual Soil Moisture Accounting (SMA) model. The simulation of runoff, which shows up as streamflow in a river, using the SMA is accomplished with assumed percolation characteristics as available moisture is distributed through the soil mantle. The model contains two zones, an upper and lower zone, each with their own tension and free water components. Parameters in each zone determine percolation characteristics between zones and the capacity of the zones. Some twenty parameters control the direct runoff, surface runoff, interflow and baseflow. The advantage of the SMA over the API is the longer term memory which is beneficial in prolonged dry periods.

The utilization of the SMA involves the calibration of an individual basin based on historical time series of temperature and precipitation, and comparing a simulated hydrograph with the observed streamflow. The modeled streamflow hydrograph is made to simulate the observed historical hydrograph by varying the model parameters values in the course of several model computer runs. Therefore, the assumption is that if the conceptual model can simulate observed historical streamflow with associated precipitation and temperature patterns, then the same model using the parameters obtained from calibration of the basin are be used to forecast hydrographs forward in time based on current and/or future precipitation and temperatures.

The NWS uses the Ensemble Streamflow Prediction (ESP) procedure to create long-term probabilistic forecasts of streamflow and other hydrologic variables. This technique is able to couple historical temperature and precipitation time series using current antecedent soil moisture conditions to produce conditional simulations of streamflow for a given future window of time. Probabilistic products and informational displays are then created from these conditional simulations.

The record flood of 1997, which occurred on the Red River of the North, has heightened interest in the Advanced Hydrologic Prediction System (AHPS) which was recently demonstrated on the Des Moines River in Minnesota and Iowa. AHPS has the capability to extend lead times out to weeks and months with products that provide relative uncertainty of hydrologic variables, i.e., discharge, volume and river stage. AHPS displays have been developed and reviewed by users to improve the transfer of hydrologic information to the decision makers. As pointed out in a recent publication (Pielke, 1997), there is mounting evidence that users of NWS flood warning and crest forecasts perceive and interpret NWS outlook products, prepared for the upper Midwest of the United States for many years, with various degrees of understanding and uncertainty. As now being suggested, it's likely to be the most important step in the process will be to better understand the "effect" that advanced hydrologic forecasts have in making reliable judgements regarding flood mitigation activities. The point is where to focus resources. More sophisticated information coming on line will require greater understanding by users to maximize the utility of improved hydrologic and scientific approaches to longer-term forecasts.

HYDROLOGIC PRODUCTS

The NWS has issued snowmelt outlooks for the Red River Basin in the United States since the late 1960s. Two outlook crest values are provided. One assumes present snow water equivalent, average temperature and no future (climate) precipitation and the second crest value assumes present snow water equivalent, average temperature plus future "normal" precipitation. In addition, a qualitative disclaimer included with the outlook discusses the uncertainty associated with the crest values.

Short-term hydrologic crest forecasts are determined from operational model runs and generally provide lead times out to a few days. These products are issued periodically when significant precipitation occurs.

Preliminary findings and recommendations from the National Oceanic and Atmospheric

Administration (NOAA) Disaster Survey of the April 1997 flooding on the Red River of the North, discussed at an interagency post flood meeting, identified the activities and focus the NWS is hoping to achieve for the Red River Valley in the United States (Johnson, 1997). Conceptional modeling and more advanced informational displays of hydrologic information highlight their findings. To this end, AHPS procedures need to be developed.

For AHPS to be implemented on the Red River of the North, several major development actions need to be accomplished. First, calibrating the basin using the SMA model. Second, implement the ESP procedure, and third, implement AHPS. This simplistic view of implementing AHPS does not begin to included dozens of hydrologic, modeling, routing and hydraulic issues that need attention and completion prior to bringing AHPS on line operationally. A multi-year effort and significant resources will be required. The NWS is in the process of determining what investments are needed before any time frame can be projected for an operational AHPS.

Past products for outlooks and more routine hydrologic forecasts have generally been tabular in nature and limited to short time frames. With the AHPS graphical displays greater amounts of information is relayed to users in probabilistic terms for longer periods of time. In Figures 2 and 3, are examples of displays showing the ESP Probability Interval Plot and the ESP Conditional Exceedance Plot respectively. These examples of AHPS products are beginning to meet product enhancement request voiced by emergency and water resource managers since the Great Flood of 1993 on the Des Moines River Basin in Iowa.

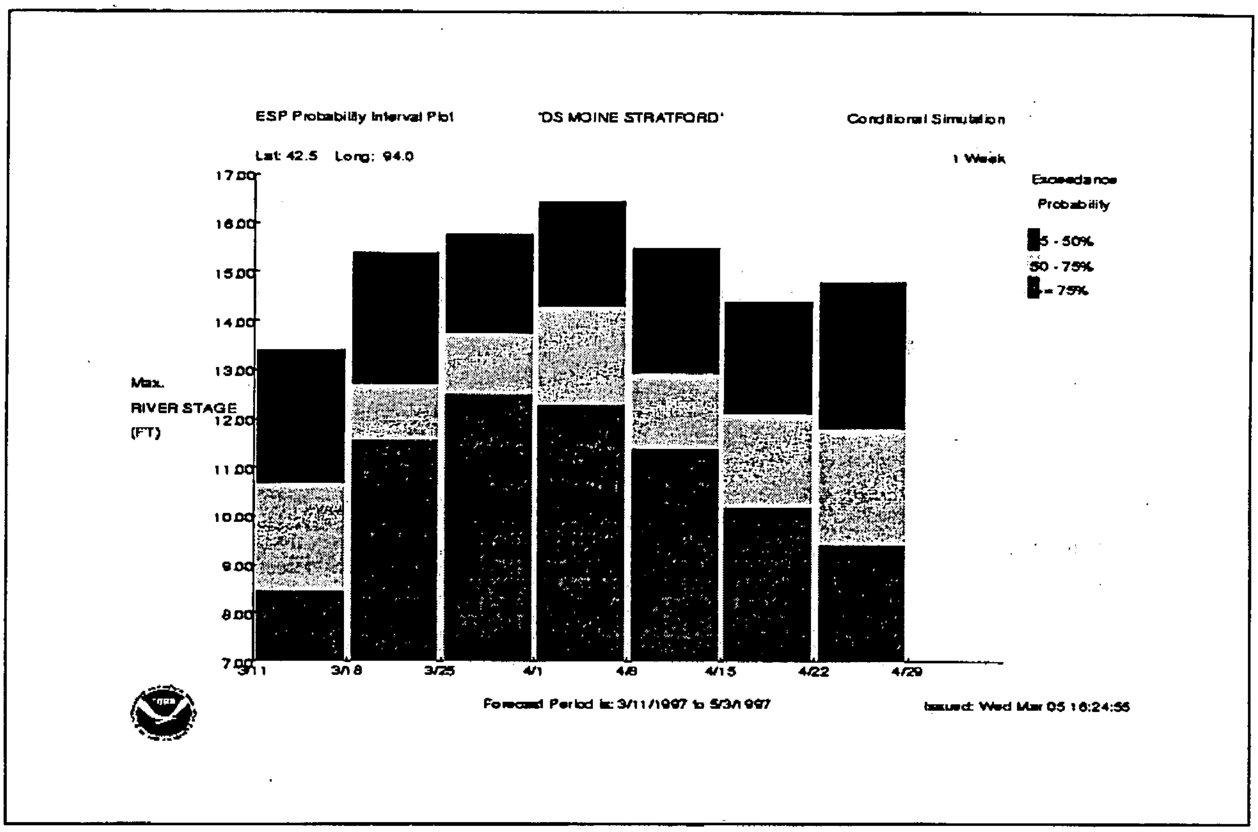


Figure 2. ESP Probability Interval Plot for the Des Moines River at Stratford, Iowa. This example is for weekly intervals covering a 60 day forecast period from 3/11/97-5/3/97.

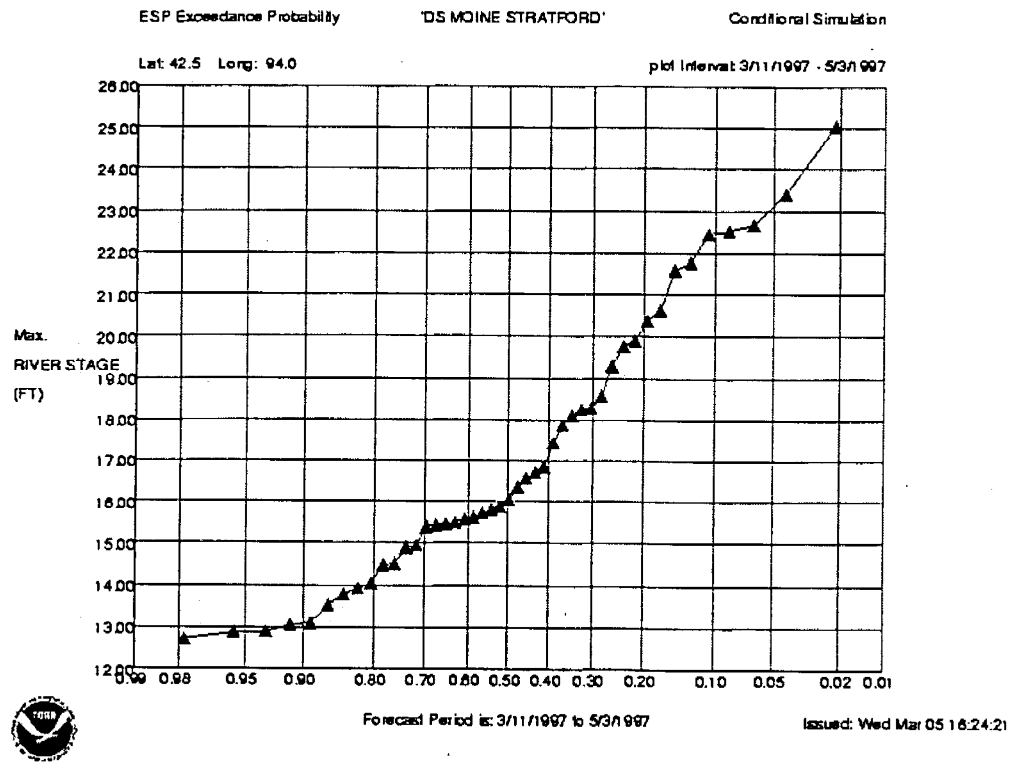


Figure3. ESP Conditional Exceedance Probabilities for the Des Moines River at Stratford, Iowa. The plot is for the forecast period from 3/11/97-5/3/97.

SUMMARY

Experience gained and feed back from users during recent major flood events (1993 & 1997) indicate that the NWS must continue to improve all components of the NWSRFS and provide for the establishment of AHPS. Further NWS modernization technologies will allow hydrologic warning services to take full advantage of AHPS. Discussions with cooperating agencies and local officials are on-going toward sharing of resources for development and network issues. The Red River of the North basin is being assessed at the highest possible priority for SMA, ESP and AHPS development. Therefore, the issuance of probabilistic displays must be fully explored and understood by users if these technically advanced informational products are maximized.

REFERENCES

Braatz, Dean T., J. B. Halquist, R. J. Wavrin, J. J. Ingram, J. J. Feldt and M. S. Longnecker, February 1997: NWS Hydrologic Products and Services: Moving from the Traditional to the Technically Advanced. Preprint from 13th Conference of Hydrology. American Meteorological Society, Long Beach, CA.

Braatz, Dean T., J. B. Halquist, M.M. DeWeese, L. W. Larson and J. J. Ingram, January 1998 (draft): the Advanced Hydrologic Prediction System: Moving Beyond the Demonstration Phase. To Be Published from the 2nd Symposium on Integrated Observing Systems, American Meteorology Society, Phoenix, AZ.

Johnson, Edward, September 1997: Personal Conversation, National Weather Service, Silver Spring, MD.

Pielke, Jr., Roger, September 1997: Meeting the Promise of Flood Forecasting. Natural Hazards Observer, Volume XXII, Number 1. Natural Hazards Research and Applications Information Center, Institute of Behavioral Science #6, University of Colorado, Boulder, CO.

National Weather Service, August 1997: Advanced Hydrologic Prediction System (AHPS): Demonstration of Modernized Hydrologic Services for the Des Moines River Basin, Iowa. HRL Publication #366, National Weather Service, Silver Spring, MD.

Stalling, E. A., and L. A. Wenzel, September 1995: Organization of the River and Flood Program in the National Weather Service. Weather and Forecasting, Vol. 10, No. 3, American Meteorological Society, Boston, MA.

Flood Proofing Program
Home, Business and Community

The spring flood of 1997, which has been referred to as the "Flood of the Century", caused extensive damage to homes, businesses and previously constructed flood protective structures. Many residents were unable to return to their homes and places of business because of the devastation.

The federal and provincial governments announced a flood proofing program on July 16-18, 1997. The objective of the project is to eliminate future damage and losses due to flooding. The program is patterned after similar initiatives that were launched after the 1966 and 1979 floods. It provides both technical and financial assistance to communities for building or enhancing ring dikes and helps individual homeowners, farms and businesses to raise foundations, construct dikes and pads or relocate within protected communities or other areas not flood prone. Private property owners who participate in the program and meet Water Resources standards get their 20 percent deductible for their disaster assistance claim waived by the Manitoba Emergency Management Organization (MEMO).

Manitoba Natural Resources, Water Resources Branch administers the flood proofing program and works closely with the Manitoba Emergency Management Organization to identify the property owners who are in the most urgent need of assistance. Priority for receiving funds goes to property owners whose homes have been destroyed or who are not able to live in their homes because of extensive structural damage.

To help property owners who are unable to secure commercial financing, the province provides loans at a competitive rate through the Manitoba Agricultural Credit Corporation (MACC). For eligible projects, there is no cap on what individuals can spend or borrow through the MACC.

Eligible costs in the private property program include:

- raising buildings on pads or moving buildings, preparing a suitable foundation or basement including the installation of sewer and water services and the cost of a suitable building lot, 75 percent of costs up to a maximum of $30,000 or

- constructing ring dikes to protect residences and outbuildings such as barns, machine sheds and grain bins, 75 percent of costs up to a maximum of $ 0,000 or

- terracing around the foundation of already raised buildings in lieu of diking, 75 percent of costs up to a maximum of $4,000.

All works must meet a minimum flood proofing standard of the 1997 flood level plus two feet. This is the new Flood Protection Level.

Application forms, fact sheets and further information on the flood proofing program is available from the Flood Recovery Information Offices in St. Adolphe, Rosenort and Letellier and all Manitoba Natural Resources Offices in or near the flooded area.

Chuck Whalen
Water Resources Branch

Research Initiatives

Robert W Tait
Disaster Research Institute
University of Manitoba

Abstract

As the waters of the Red River receded, a group of academics gathered to discuss their experiences and interests in the events that were transpiring. The outcome of the discussions was the formation a research network (FLOODNET) consisting of individuals from the sciences, social sciences, humanities, engineering, agriculture and health sciences that exists for the purpose of developing and encouraging research on flooding in the Red River Valley. The network's initial activity was to host a forum in which research issues could be identified. Invitations to attend a research workshop were extended to: representatives of communities in the valley, members of government and non-government organizations that were involved with different aspects of the flood, and to the academic community. Approximately one hundred and twenty individuals subsequently registered for the workshop that was held in September.

The workshop, featured addresses, panel, and round table discussions. The four round table discussions were structured much like the present workshop in that the temporal stages of the flood (planning and prediction; reacting to the flood; impact of the flood; human response to the disaster) served to focus discussion. Each round table discussion was primed by three questions: What do we know about the topic? What do we need to know about it? And, how do we go about finding out about what we need to know? The discussions, often lively and animated, produced more than 300 issues that could serve as the basis of future research. The issues cluster about three themes: technological needs; societal reactions and the interactions of the two. Surprisingly, understanding societal reactions, both to the flood and to how the Province responded to it, emerged as the greatest need for future investigation. The presentation will elaborate on these themes and indicate the steps that FLOODNET is taking to foster research programs directed at them.

Canadian Water Resources Association
Red River '97 Flood Symposium
The Flood of the Century
October 22 & 23, 1997

Turnbull Drive/Red River Drive Dike

Dr. Norman R. Hunter
President (1997), The 768 Association Inc.

Introduction:

The first major test of the Winnipeg Floodway Diversion Control system occurred in the spring of 1974 when flood waters reached the second highest (after the famous 1950 flood) elevation of the 20th Century. That spring the residents of the Turnbull Drive (City of Winnipeg) and Red River Drive (RM of Ritchot) area, which is immediately south of the control gates and on the west side of the Red River (Fig. 1), diked their residences against the rising waters. Unfortunately, many homes where diking was adequate were flooded because of backwashing when the gates were raised too rapidly causing an overflowing of many dikes. This event sensitized the Turnbull Drive/Red River Drive residents about the operation of the control gates. In 1979 another major flood occurred with an elevation which displaced the 1974 flood as the second highest of the 20th Century. During this flood all the homes which were diked successfully defeated the flood waters. By this time Provincial officials responsible for the operation of the control gates had been made aware of the problems which had been created by the control gate operation in 1974. Due to a more careful control of the gates there was little major backwashing following each raising of the gates, though backwashing could still be observed up to one-half a kilometer south of the structure.

Immediately following the 1979 flood the residents in the area formed an incorporated association to take advantage of a Federal/Provincial jointly funded dike construction program. This association, The 768 Association Inc., set about to collect contributions from the 22 homeowners in the area in order to obtain the governmental funding under a matching formula. By the fall of 1979 a dike had been constructed to enclose the homes with a dike at elevation 768 feet above sea level (2 feet above the 1950 flood level for the area). This dike used Provincial Highway 75 as the west boundary (Fig. 1). One key weakness in the diking structure was a slip plane weakness at the southeast corner which prevent the dike from being raised in that area above the elevation of 762 ft.

During the years from 1979 to 1996 Association Dues were collected from the homeowners in anticipation of a future flood. That future flood came in the spring of 1996 when flood waters reached an elevation between the 1974 and 1979 floods (Fig. 5). The Association was able to raise the southeast corner to an elevation of 769 ft during the flood and lower the dike as the water receded thus successfully protecting the residences from flooding. At this stage the south east corner was lowered to 764 ft elevation.

The 1997 Flood - Preparations:

By mid-February of 1997 it became obvious to the executive of The 768 Association Inc. that 1997 had the potential to involve more severe flooding than had been experienced in 1996. Arrangements were made with a local contractor to raise the southeast corner again. In addition, contact with the City of Winnipeg indicated that sufficient sandbags would be made available to raise the portion of the dike in the City to an elevation of 770 ft. Indeed, 30,000 sandbags were delivered on April 3rd to two sections of the dike in anticipation of future sandbagging. Some hope had developed by late March that flooding would be less severe than anticipated because of excellent spring melting and local runoff. However, with the "Blizzard of the Century" on April 5th and 6th all hope was dashed. In addition, the 30,000 sandbags on the dike were frozen and under snow.

The blizzard changed the approach to the flood dramatically. No longer did The 768 Association Inc. have the financial resources necessary to fight the flood. On the other hand and fortunately, a great deal of professional and personal resources was available. Mr. Rob Loudfoot (City of Winnipeg engineer) and Rob Duerksen (PCL engineer) provided a great deal of local resident engineering resource. A number of other residents had lived in the area for over five decades and had a lot of practical experience. The experience of fighting the 1996 flood would also prove valuable during the whole process. At this stage it was concluded that it was necessary for the City of Winnipeg to throw there resources into the fight and they initiated a major program to raise the dike within the City and a portion of the RM of Ritchot up to 771 ft (it was decided later to raise the dike up to 773.5; this decision proved fortuitous because of the final flood elevation). The City also undertook the raising of the east northbound lane of Highway 75 to the same elevation. Meanwhile, the Association engaged their contractor to raise the major portion of the dike in the RM of Ritchot (south east corner, and west from Red River Drive to Hwy 75) to the elevation of 773.5 ft.

Fortunately, generally good dike construction weather persisted during this phase so that after a hectic ten days everything was (seemed to be) ready. When the floodway control gates were raised for the first time on ~10:00 pm on Monday, April 21st most residents felt that the best that could be done had been done. No one anticipated the rate at which the control gates would be raised, nor how dramatically that rapid raising of the gates would affect the ultimate flood elevation!

The 1997 Flood - Evacuation:

The order to evacuate by noon on Saturday, April 26 which was issued on Wednesday, April 23rd came as a surprise to many residents. Resentment of the decision being made without additional consultation with the Association caused added stress for many residents. Individuals who had lived in the area for over fifty years, and had successfully fought the 1948, 1950, 19754, 1979 and 1996 floods (and a collection of minor ones along the way) found this decision very difficult to live with. The added stress of the forced evacuation probably contributed significantly to the death of one resident on the afternoon of the evacuation. The manner in which the evacuation was handled was a harbinger of the problems which the residents would face throughout the whole period of evacuation. Despite much consternation the area was completely evacuated by noon on Saturday. Promises that the City would ensure complete security of the area alleviated many fears. However, while the City Police provided security (i.e., control of access to the area) the actual execution of that promise created extreme problems for the Association. Attempts had been made repeatedly for the City to establish an approved list of residents who would monitor the dike over the time of evacuation. By the time of evacuation no list had been approved. Indeed, it would take several days to obtain such an approval after evacuation, but the actual entry into the area for dike monitoring continued to be a major problem

The 1997 Flood - Dike Monitoring:

Despite the failure to have obtain approval of a list of dike monitors, one resident did gain access later on the day of evacuation. That resident found a leaking water valve at the pumping station which, if left unattended, would have lead to serious problems. That evening, and into the early hours of Sunday morning, major effort was required to bring the leak under control. Sunday and Monday passed without approval of the dike monitoring list. Perhaps more by luck than anything else (actually a lied a bit!), I was able to gain access to the area early on the morning of Monday, April 28th and Tuesday, April 29th in order to do a total walk of the dike to review its integrity. For a major dike of several kilometers one monitoring trip per day was simple inadequate. On the Tuesday morning a construction company employee and myself found (almost simultaneously) a major leak in the dike along the west side where a ‘plugged’ culvert under Hwy

75 had blown open. Under a head of about six feet of water, this culvert was pumping water to the inside of the dike at an alarming rate. Fortunately, with the aid of the construction company, the army was able to plug the culvert over a period of about five hours.

Those residents who were aware of the blown culvert decided that they would no longer leave the area after gaining access during the day. Some planned on staying in their homes during the evening and monitoring the dike every few hours. Prior to a major confrontation wherein the City police might have to arrest residents (even though it came close to happening) final approval for a list of resident monitors came through. The City also placed four City employee monitors on the dike beginning the evening of Wednesday, April 30th. From then on until the flood waters began to recede the resident monitors and City monitors worked in teams which toured the dike every several hours. No major problems developed and by the time of the crest a sense of victory was shared by the residents who were still in contact with the situation. By May 6th the feeling of victory was profound. Even though reentry to their residences would not be allowed until Saturday, May 24th, the stress levels for most people began to fall.

Only on reentry did most residents realize the magnitude of the damage which had occurred south of them only Red River Drive and Marchand Road. Since many residents had helped sandbag and protect those homes prior to evacuation, they also felt, to some extent at least, the pain and sadness of the residents of these homes.

The 1997 Flood - Lessons to Learn:

When one reviews the 1997 flood and, in particular, compares its progress to both the 1996 and 1979 floods (see Figs. 2, 3, 4), it is difficult not to conclude that the 1997 flood was made far worse than it should have been because of the operation of the control gates. The rapid raising of the control gates from April 21st to April 24th (Fig. 2) bought an extra seven or eight days for the City of Winnipeg to complete their flood protection program (which was quite inadequate and needed that time), but it essentially doomed the residents of Red River Drive and Marchand Road (and St. Mary's Road on the east side of the river). Within 3 days of activating the control gates the flood waters south of the gates were approaching the historic 1950 levels (Fig. 3).

Most profound, to me, was the degree by which the 1997 flood deviated from the pattern of the 1979 flood (and to a lesser extent the 1996 flood) (Fig. 4). Since >80% of the flood waters come from the North Dakota/Minnesota portion of this drainage basin, and since during the time of the flood there was no significant precipitation, and since much of the local runoff had preceded the crest period, one would anticipate a similarity between the 1979 and 1997 floods. That similarity simply does not exist. As noted in Fig. 4, the 1997 flood reached elevations of 1 to 2 feet higher than the 1979 flood at Emerson, Letellier, St. Jean and Morris. But, at Ste. Agathe the elevation was ~3.5 feet higher in 1997 versus 1979. At St. Adolphe the elevation was ~4.2 feet higher in 1997. Most dramatic, at the Turnbull Drive/Red River Drive dike (and areas immediately south; i.e., south Red River Drive and Marchand Road) the elevation in 1997 was 6.3 feet high in 1997.

The 1997 Flood - Conclusion:

If any lesson(s) are to learned from this flood it surely should be that it is patently unwise to restrict the flow of the river early on by raising the control gates in order to 'buy time' for the City of Winnipeg to get its defenses in order. Based on the 1997 flood it surely should be of highest priority that the City of Winnipeg establish permanent diking at a level which would allow flow through the city at an elevation near the point finally reached in the 1997 flood. I.e., 761 feet above sea level. This would maximize the flow of the river by optimizing the floodway/city balance and thus prevent the backup of water that resulted during the period of April 21st to 30th (Fig. 2).

Fig. 2 Differential Elevations
River Rise and Gate Rise

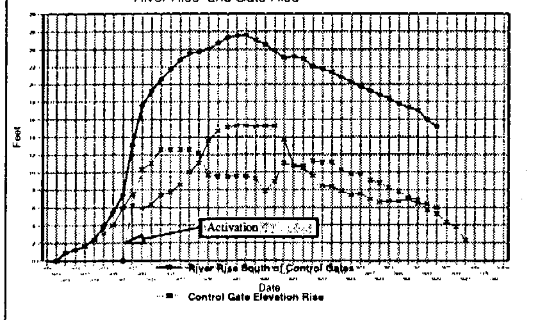


Fig. 3 Comparison of 1996 and 1997
Elevations South of Control Gates

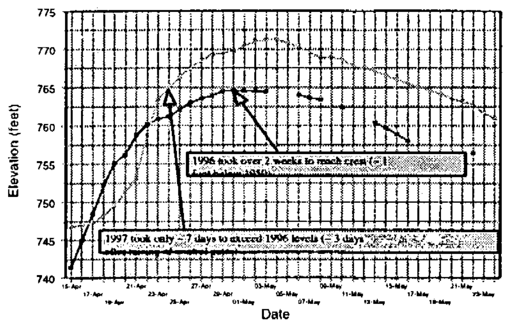


Fig. 4 Flood Crest Comparisons
1979, 1996, 1997

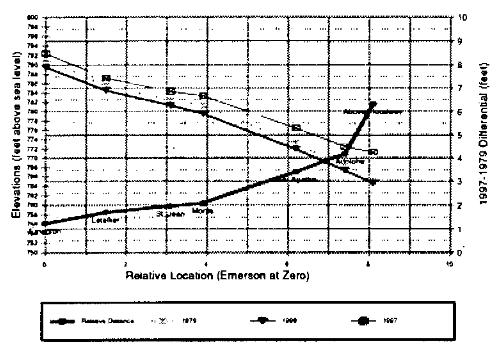
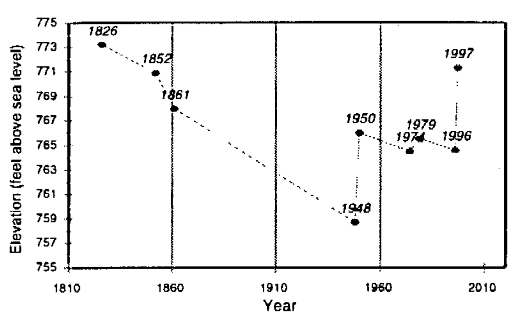


Fig. 5 Major Manitoba Floods
Crest Elevations at Floodway Entrance



The Kingston Crescent Dyke
surrounding
The Elm Park Peninsula Community
by Ed Kuiper

The City of Winnipeg is protected against flooding by four different projects: the Red River Floodway, the Portage Diversion, the Shellmouth Reservoir, and a system of dikes within the City called the "primary dikes". These dykes, built shortly after the 1950 flood, coincide more or less with existing main streets and run close to and parallel to the rivers. This is the most cost-effective location of those dikes, but many houses, situated between these dikes and the river, are thus left unprotected. When a flood threat arises, the City will provide sand bags, free of charge, but also free of responsibility.

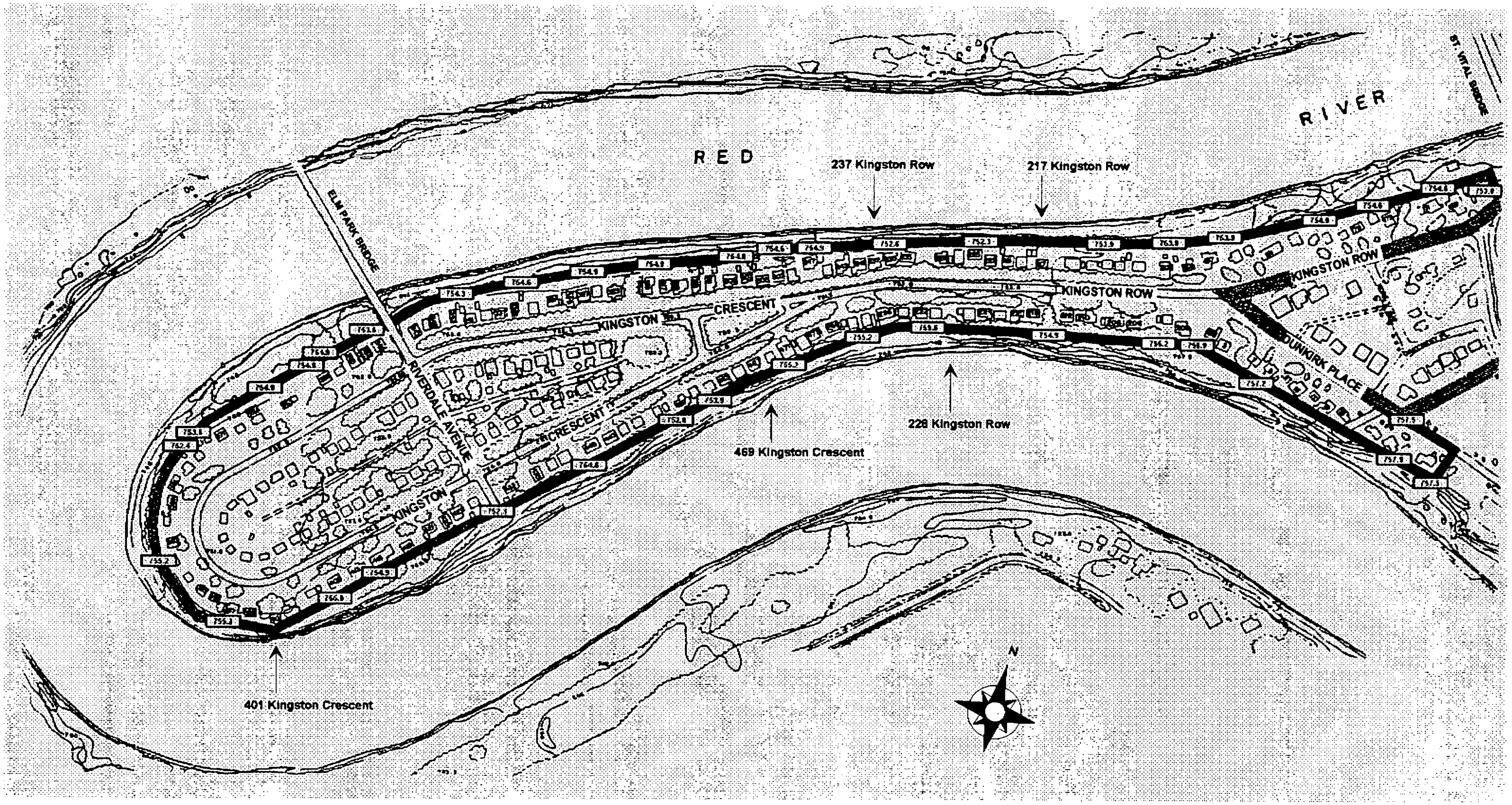
The largest cluster of houses in this situation is along Kingston Crescent and Kingston Row. As a compromise between "primary dike level" protection and no protection, the Provincial Government, in the early 1950s, built a secondary dike along the north side of the peninsula through the back yards of the houses, about two feet lower than "primary dike level". Until now, that has been sufficient.

However, during the course of the 1997 Red River flood it became evident to the Elm Park Peninsula Community that the possibility of flooding was very real. Thanks to the joint effort of the City of Winnipeg, local residents and hundreds of volunteers, disaster was avoided. Nevertheless our community is convinced that it would be highly desirable to be better prepared if a similar threat would occur again.

Preparation, in our experience, takes the form of readiness in two distinctly different ways: first, because temporary sand bagging will always be a necessity for floods of the 1997 magnitude, it is desirable to get onto the dikes and diking corridor as early as possible. Once on the dyke, it is important to have no obstructions and certainly no holes in the continuity of the dyke that would require special attention. To effect this form of readiness, legal and regulatory changes have to be made and enforced by the City. Second, in order to provide a sound base for the temporary sand bagging and to minimize the height to which it must be built, physical alterations would be necessary to some of the existing permanent diking and corridor. This could include the following:

1. The crest of the secondary dike on the north side of the peninsula should be brought to a uniform height equal to the crest elevation of the 1997 flood. Three quarters of that dike is already up to that elevation.
2. A corridor should be permanently established along the south side of the peninsula where in case of emergency, a sand bag dike can be erected. This corridor should be about ten feet wide, level across the direction of alignment, continuous from lot to lot, free from obstructions and with an elevation no lower than the crest of the 1997 flood. Three quarters of a prospective corridor has already that elevation.

To achieve these goals, three problems have to be solved: two easy ones and a difficult one.
First, an engineering study has to be undertaken to determine the exact location and design and cost estimate of the proposed works,
Second, financing of those works from various levels of government has to be found.
Third, and most difficult, agreement has to be obtained from all residents with river bank property that in their "private' back yard some work may have to be done and that this work, together with existing diking, will henceforth be protected by regulation from unapproved modification.



ELM PARK PENINSULA COMMUNITY

Existing permanent secondary dyke and/or non-dyked natural corridors

Primary dyke

754.6 Existing elevations on dyke corridor

Community Description

~West Kingston Row nos. 163 to 247, all of Kingston Crescent, Dunkirk Place odd nos. 3 to 31
~198 single residences: 149 on dyke corridor, 49 on interior of Kingston Crescent loop
~Proposed 1998 appraisal value: $30 million plus
~Length of dyke corridor: 9300 ft. (2.8 k)

OF WATER and WATER FIGHTERS: Peoples Response to Flood-1997 in the Red River Valley, Manitoba: A research agenda

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ABSTRACT

The Problem:

In April of 1997, emergency experts and managers in Manitoba declared an all out war against the rising waters of the Red River. The war was fought in all fronts with all possible gazetes and won. Cought in the crossfire were the people of the Red River Valley (RRV). The flood of the century in 1997 approached Manitoba-part of the RRV like a threatening tidal wave in April and than ebbed out in May. This image of the encroaching flood water was matched with a similar tide and ebb of concerns in Manitobans regarding safety of life and property. Generally public response was effective. In this successful flood fighting some resentment and dispute propped up in the local communities about the strategic and tactical approach to emergency flood response offered by the Province. Dispute appeared between the local first responders (LFR) and the Provincial response coordinators (PRC), and between the some other responding agencies (Winnipeg Free Press, May 21 and June 15, 1997). However, these disputes were handled tactically and resolved. Dominant social scientific studies identify crucial differences in their judgments of risk made by experts and the people.

The Context:

The population of the Red River Valley in Manitoba is composed of diverse groups such as the Aboriginals, Mennonites, Huttarites, French, Metis, and English. These various ethnic groups are relatively socio-culturally distinct. For example, the people of the first nation maintains a socio-cultural characteristics distinct from the rest of the society. Currently this distinction is being reshaped and intensified through their pursuit of self-detemination and governance. Several studies elsewhere in North America suggest ample reasons to be concerned about ethnic peoples effective participation in preparedness and prevention for an emergency. Yet no comparable studies have examined the relationship between hazard awareness, emergency preparedness and ethnicity in Canada in general, and in Manitoba in particular.

The Manitoba Emergency Measures Organization (MEMO), the Provincial disaster management agency, provides necessary support to the local communities when local capacity is overwhelmed by an emergency. Emergency measures undertaken during the April-May flood of 1997 generated some bitter criticism of provinces response in some of the communities in the RRV. This reflects different perception of the flood as an emergency and local expectation of appropriate response measures. Research is needed to understand the level of awareness of, and attitude towards disasters and disaster management in Manitoba. An essential part of this researchcould be assessment of the status and awareness of emergency preparedness within various rural communities in the Red River Valley in the aftermath of the so-called flood of the century in 1997. Factors that might differentiate individuals and communities must be considered in order to understand variability in response to flood hazard. Similarly, attitude within the population (acceptance and/or opposition) towards government emergency policies fruitfully evaluated on the basis of shared values, beliefs, knowledge and life experiences. Empirical evidence suggests that prior beliefs and past experiences, knowledge and emergency management training influence the subsequent evaluation of environmental hazards (Perry and Mushkatel, 1986, Rossi, et.al. 1982). Ethnicity is

correlated with certain life situations relevant to risk evaluation, such as access to societal resources that could mediate the effects of a hazard (Perry and Greene, 1982; Turner and Kiecolt, 1984). We should also ask what role each local comminities should play and how in order to use peoples knowledge besides those of the experts. esearch on water related disasters needs to address questions,such as:

* is there any difference in perception, and therefore, response to natural hazards in different communities?
* does difference in perception and response cause any conflict between experts and local peoples interest?
* in responding to an emergency, what role the hazard-prone people as the Local First Responders (LFRs), can play? We encourage peoples participation in all crucial social matters? If people are to bear some responsibility in the matter of damage control, shouldnt they be allowed to decide what to do, how to do, and when as regards to management? This paper contemplates to address this issue of peoples participation in emergency management.

MEDIA PERSPECITVES

Iris Yudai,
CBC Radio

The 1997 flood wasn't just the Flood of the Century. For the media, it was the Story of the Century. Local newpapers, television outlets and radio stations poured all of their resources into covering the event. Reporters packed up their their notepads and cameras, as well as rubber boots and hipwaders. They travelled by truck, boat and helicopter to every corner of the Red River Valley from Grand Forks to Gimli. TV stations broadcast live from the floodway and the Forks. Manitobans were able to find volunteers and backup valves through radio phone-in shows and 1-800 lines.

But the media didn't just cover the story.

It became part of the story.

CBC Radio reporter Iris Yudai brings you a behind-the-scenes look at how the Manitoba flood shaped the media.

CWRA ACRH

Canadian Water Resources Association

Association Canadienne des Ressources Hydriques

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