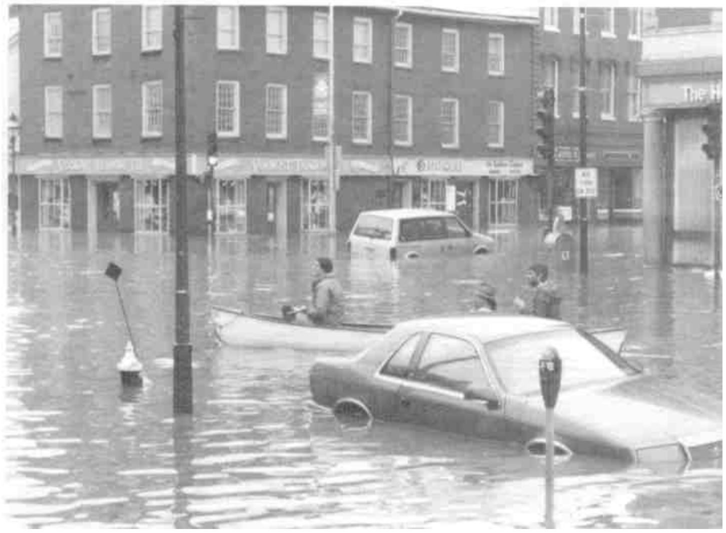
Montpelier Flood Hazard Mitigation Plan



City of Montpelier

Department of Planning and Development

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Written in Cooperation with:
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I. Introduction and Background

The City of Montpelier has been severely affected by flooding of various forms since its founding in the 1700s. In more recent times, residents, city government, state government, the Army Corps of Engineers, and the Federal Emergency Management Agency have constructed flood mitigation devices, enacted various forms of legislation, and initiated numerous activities and programs designed to mitigate flooding and flood damage in the city. While many of these strategies have been successful in reducing some forms of flooding, the threat of flooding and flood damage remains significant. Past floods have caused millions of dollars in damages to the city and its residents and the potential exists for further damage to the city's buildings, property, infrastructure, and people. This plan presents strategies to mitigate future flood losses in the event flooding does occur.

A. Plan Authority

This plan was authorized under Section 553 of the National Flood Insurance Reform Act of 1994. Section 553 authorizes a Flood Mitigation Assistance Program to provide grants to communities for planning assistance. The purpose of the Flood Mitigation Assistance Program is to assist local governments in funding cost-effective actions that reduce or eliminate the long-term risk of flood damage to buildings, manufactured homes, and other insurable structures as well as reduce or eliminate claims under the National Flood Insurance Program (NFIP) through mitigation activities.

B. Purpose of Flood Hazard Mitigation Plan

The purpose of the Flood Hazard Mitigation Plan is to assess the flood risks which confront the City and community of Montpelier and to articulate a comprehensive strategy for implementing technically feasible flood mitigation activities. The plan will outline the risks associated with flooding, describe the existing conditions in Montpelier, describe existing mitigation programs and activities, describe previously studied mitigation strategies, and present a comprehensive list of mitigation strategies and activities. The mitigation strategies will be prioritized to assist in the implementation of the plan.

C. Required Elements of the Flood Hazard Mitigation Plan

According to the enabling legislation of the Flood Mitigation Assistance Program, at a minimum, plans must include the following elements:

1. Description of the planning process and public involvement
2. Description of the existing flood hazard and identification of the flood risk, including estimates of the number and type of structures at risk, repetitive loss properties, and the extent of flood depth and damage potential.

3. The applicant's flood management goals for the area covered by the plan.
4. Identification and evaluation of cost-effective and technically feasible mitigation actions considered.
5. Presentation of the strategy for reducing flood risks and continued compliance with the NFIP, and procedures for ensuring implementation, reviewing progress, and recommending revisions to the plan.
6. Documentation of formal plan adoption by the legal entity submitting the plan.

D. Scope of Flood Hazard Mitigation Plan

The City of Montpelier is located within Washington County just north of the geographical center of Vermont. The plan will address flooding within the boundaries of the City of Montpelier as it has been known to occur and as it may occur in the future. Flooding is a phenomenon which is affected by and affects an area much larger than one municipality; however, the plan will focus solely on mitigating flooding in Montpelier.

E. Planning Process and Public Involvement

This flood hazard mitigation plan has been developed through the involvement of Montpelier citizens, the business community, the Federal Emergency Management Agency (FEMA), the City Planning Commission, the City Council, and various municipal departments. In December, 1997 a survey and informational brochure were mailed to all of the property owners in the flood plain. The informational brochure was meant to inform flood plain property owners of the history of flooding in Montpelier, municipal regulations pertaining to flooding, and methods to reduce the risk of flood damage or injuries related to flooding. The survey asked questions relating to property owners' knowledge of flood issues, physical aspects of their buildings, whether owners carried flood insurance or knew it was available, and their desire for various financial incentives and programs to help reduce the risk of flood damage to their properties. The response to the survey was commendable with over 20% of the survey forms returned. Over 135 survey responses were received (20.5%), the results of which are summarized in Chapter Five.

The City hosted a flood plan workshop on February 5, 1998 to present results of the survey, review past flood events, and solicit recommendations and comments from the public. The workshop was attended by citizens, FEMA officials and representatives from the city's Police, Public Works, and Planning Departments.

The draft flood hazard plan was reviewed by the Montpelier Planning Commission at two public hearings. The Montpelier City Council reviewed the plan over the course of two public hearings and adopted it at their meeting on July 22, 1998.

F. Existing Studies and Reports

1. *The Flood, November 3-4, 1927, Montpelier, Vermont*. Provides a narrative description and extensive pictorial evidence of damages caused by the Great Flood of 1927.
2. *Document #17, 71st Congress, 3rd Session: Winooski River, Vermont*, February 21, 1931. A comprehensive report describing the Winooski River describing potential improvements in response to the 1927 flood.
3. *Flood Plain Information, Winooski and North Branch Rivers, City of Montpelier, Vermont*, Department of the Army, New York District, Corps of Engineers, July 1970. This report presents historical and future flood events in accordance with the Flood Control Act of 1960. The report presents inundation plans and water surface profiles for the immediate and standard project flood events.
4. *Flood Insurance Study - City of Montpelier, Washington County, Vermont*, Department of the Army Corps of Engineers, New York District, May 1975. The report contains considerable data regarding flood hazard zones and flow data on the branches and reaches in the area.
5. *Advanced Remedial Measures, Ice Jam - Montpelier, Vermont*, Emergency Technical Assistance Team, January 1978. Intended to assist the District Engineer in determining whether to undertake advanced remedial measures to alleviate present and potential flooding due to an ice jam one of Montpelier's rivers.
6. *Flood Insurance Study - City of Montpelier, Washington County, Vermont*, Department of the Army Corps of Engineers, New York District, August 1981. Describes the flood hazards in Montpelier and intended to be used to further proper land use and floodplain development.
7. *Interagency Hazard Mitigation Team (IHMT) Report*, Region I IHMT, 1992. Presents the findings of the IHMT that met in Montpelier to identify and recommend mitigation measures to allow federal, state, and local governments to better prepare for future floods.
8. *Montpelier Ice-Jam Flood of 1992*, U.S. Department of the Interior, U.S. Geological Survey. Provides a detailed description of the formation of the ice-jam, subsequent flooding of Montpelier, and breakup of the ice jam.
9. *Ice Jam Mitigation at Montpelier, VT: Winter 1992-93 Program and Long Term Options*, Cold Regions Research and Engineering Laboratory. September 3, 1993.
10. *Winooski River Floodwater Management Study Montpelier, Vermont*, U.S. Department of Agriculture, Soil Conservation Service, February 1994
11. *Winooski River Flood Control Reconnaissance, Study City of Montpelier, Vermont*, DuBois and King Inc., March 1994.
12. *Montpelier Rivers Report*, Hans Estrin, March 1995.

II. EXISTING CONDITIONS WITHIN THE STUDY AREA

A. Study Area

Montpelier, established in 1791, is located in the upper watershed of the Winooski River. The layout of the city was largely influenced through geography, with riverside development offering appealing transportation routes and mill sites while homes were built on higher ground. Early development included saw and grist mills, inns, churches, and schools. By 1858, the City's main streets achieved their current alignments parallel to the rivers and the commercial core of the city was well established near the confluence of the Winooski and North Branch Rivers. The 1996 figures produced by the Department of Health indicate a population of 8,432.

The south central section of Montpelier lies within the floodplain of the Winooski River and three major tributaries: the Dog River, the North Branch and the Stevens Branch. Included in this section of the city is the historic district; the downtown business district with commercial and retail businesses; federal, state and municipal office buildings; police and fire departments; numerous churches; the City's high school and an elementary school; restaurants; and other public facilities.

The study area consists of the section of Montpelier which lies within the 500-year floodplain of the Winooski River and its tributaries, which begins at the City of Montpelier/Town of Middlesex Town line and extends approximately 5.5 miles up the Winooski River to the City of Montpelier/Town of Berlin line. Approximately 1.3% of Montpelier lies within the 500 year flood plain and 7.2% within the 100 year flood plain. The study area also extends approximately .5 miles up the Dog River, .75 of a mile up the North Branch and .5 miles up the Stevens Branch of the Winooski River 9Figure 1 Site Location Map)

B. Topography

The City of Montpelier is located on the western slopes of the Green Mountains, a northward extension of the Appalachian Mountain range. The general area consists of rolling hills, high ridges, and terraces and low lying floodplain areas. The maximum elevation, approximately El. 1,200 feet above sea level, is located atop a hill in the northern comer of the city and the low area, El. 494, is located on the Winooski River at the west central corner of the city. In addition to the Winooski River and its tributaries, numerous mountain streams and brooks flow in and around the surrounding area. The high mountainous terrain and low-lying floodplains provide for great topographic relief. As a result, flash floods are frequent during high intensity storm events. In addition, this relief causes fast releases of river ice during break up, resulting in nearly instantaneous ice jams and subsequent inundation of the floodplains.

Figure 1 to be available separately.

C. Watershed Characteristics

The headwaters of the Winooski River begin in the northeast corner of Washington County, in the Town of Cabot. The river flows in a northwesterly direction for approximately 90 miles until discharging four miles north of Burlington into Lake Champlain. The total drainage area of the Winooski river is approximately 1,080 square miles and drains 11.9 percent of the State of Vermont.

The Winooski River has seven (7) major tributaries: the Huntington River at Jonesville, the Little River at Waterbury, the Mad River at Middlesex, the Dog River at Montpelier, the North Branch at Montpelier, the Stevens Branch at Montpelier and the Kingsbury Branch at East Montpelier.

The drainage area at the downstream limit of the study area is 491 square miles, which includes the Dog River, North Branch, Stevens Branch and Kingsbury Branch. The North Branch, Stevens Branch and Dog River drain 80, 129, and 94 square miles respectively. In downtown Montpelier, at its confluence with the North Branch, the drainage area of the Winooski River is approximately 390 square miles and decreases upstream to approximately 200 square miles above the confluence with the Stevens Branch. Roughly 33% of the watershed's area lies behind three flood control dams at Wrightsville, East Barre, and Molly's Falls. (Figure 2 Winooski River Watershed)

D. Geography

The geography of the study area is characterized by a narrow valley floor ranging in width from approximately 500 up to 1,500 feet. Steep hillside slopes form the walls of the valley which extend up to 500 feet above the Winooski River.

According to the Vermont Geological Survey, the physiographical location of the study area is within the New England Uplands Province as described by Fenneman (1938). Tectonically, the study area is located in the Crystalline Appalachians Province as classified by King (1959).

Soils in the region vary in depth, covering deltas, deposits of gravel, sands, and clays. The upland material is predominantly glacial till and the valley floor consists of glacial deposits, sediments, and alluvial soils. The river bed consists of rock outcrops and alluvial deposits of gravels and sands. Silt accumulations are found behind existing dams and naturally slowflowing regions.

E. Climate

The State of Vermont is located within the temperate region of North America. The study area is representative of the average statewide climate, which is subjected to the four full seasons of the

Figure to be available separately.

Figure 2. Winooski River Watershed

Figure to be available separately.

year.

The long term, average annual temperature is approximately 42°F as recorded at the National Weather Service, MONTPELIER FFA AP, climatological recording station located at the E.F. Knapp State Airport in Berlin, Vermont. The warmest month is July, with a long term average temperature of 67°F. The coldest month is January, with an average temperature of 16°F degrees.

F. Precipitation

The mean annual precipitation recorded at the MONTPELIER FAA AP recording station is approximately 34 inches with the greatest average monthly total occurring in August and the least in January.

The average annual precipitation within the City limits ranges from 40 inches in the northern area of higher elevations, to 34 inches in the southern central valley locations.

The State of Vermont and the New England region is subjected to transcontinental, coastal, and hurricane-type storm events. The transcontinental storms are more numerous and generally produce lower intensity, longer duration rainfall. Coastal and hurricane storm events result in higher intensity, short duration rainfall.

G. Existing Water and Land Related Projects

Numerous water and land related projects constructed on the Winooski River have a direct affect upon the study area.

Reservoirs

Two flood control reservoirs are located upstream of the study area. Both were designed and constructed by the U.S. Army Corps of Engineers in the 1930s following the aftermath of the 1927 flood, and are currently owned and operated by the State of Vermont.

- The East Barre Flood Control Reservoir is located on the Jail Branch in East Barre. Construction was completed in 1935 and provides flood control to 38.7 square miles of watershed. This reservoir is located approximately 13.2 river miles upstream of the USGS Montpelier gage.

- The Wrightsville Flood Control Reservoir is located on the North Branch in Middlesex. Construction was completed in 1935 and provides flood control to 68.1 square miles of watershed. This reservoir is located approximately 4.5 river miles upstream from the USGS Montpelier gage.

Dams

- The Levesque Station (former Montpelier Hydroelectric Dam Number 4) is a hydroelectric dam located on the Winooski River in the Town of Berlin approximately 4.7 river miles upstream of the USGS Montpelier gage. This dam does not have storage capacity for fluvial events, but may provide ice retention capacity.

- Montpelier Dam Number 3 is located on the Winooski River in Montpelier at river station 180+00. This dam was originally constructed to provide condensation water for a steam plant. The existing remnant of the original station is an approximate 6 foot high, 181 foot wide concrete gravity dam with no operating control gates

- The Bailey (Clothespin) Dam was constructed in 1938 to replace a deteriorated timber crib dam which was constructed in the mid 1800s. The dam was removed and replaced with a low broad crested weir by the U.S. Army Corps of Engineers in 1975. This new weir is not considered a major obstacle to ice movements.

- Green Mountain Power Number 2 is a hydroelectric dam located in Middlesex Gorge in the town of Middlesex. The dam is approximately 5.8 river miles downstream of the USGS Montpelier gage. It has been suggested in previous studies that the pool behind the dam, which extends approximately 18,400 feet upstream, results in thick, strong sheets of ice cover which impedes the progress of ice moving downstream.

- The Lane Shops dam is an abandoned dam located approximately a half mile north of the Winooski River on the North Branch. The dam does not appear to be a major impediment to river flow or ice movement.

Other Impediments and Improvements:

- Many bridges are located in the study area and include railroad bridges, foot bridges, and automotive bridges. There are six automotive bridges which span the Winooski River, many of which have abutments which extend into the river. The railroad bridge located in the slow moving reach between the Bailey Avenue and Main Street bridges has three abutments which extend into the river and were significantly affected in the 1992 ice jam. The north branch river has seven automotive bridges and two foot bridges which span the river. The Dog River has one automotive bridge while the Stephens Branch has no bridges in the study area.

- Significant channel modification projects have been undertaken on the Winooski and North Branch Rivers. These rivers have been straightened and narrowed through the addition of walls since the early settlement period of Montpelier. Particularly in the downtown area near the confluence of the two rivers, few natural areas of the rivers remain. In the downtown area, the rivers have been narrowed significantly, particularly the North Branch, with high walls surrounding the river on both sides.

H. Land Use

Current land use within the Montpelier is predominately residential; however, the area located within the floodplain is predominately retail, commercial and institutional. Main Street and upper State Street is mostly small business retail stores. State Street also consists of many state and locally owned buildings including the historic State House and Pavilion Building. The federal building and county court house are also located on State Street and are prone to flood damages.

The region of Washington County surrounding Montpelier is relatively rural. Montpelier, Barre City and the connecting U.S. Route 302 (Barre-Montpelier Road) corridor serve as the development center of the county.

I. Environmental Resources

An inventory of environmental resources was collated by DuBois and King, Inc., from data available through the U.S. Fish and Wildlife Service, the Vermont Agency of Natural Resources Department of Fish and Wildlife, the ANR Non-game and Natural Heritage Program, and the ANR Water Quality Division. In general, the study area of the Winooski River offers very limited environmental habitat or species due to urban degradation or the encroachment of development into the stream bed zone. The majority of the study area can be characterized as having thin to nonexistent riparian zones (and therefore extremely limited flora or fauna) with a stream bed that is generally wide and shallow and which is dominated by shifting sands and gravels (providing poor aquatic habitat).

There are no federally listed or proposed endangered or threatened species within the study area. The State of Vermont has identified a limited habitat for a freshwater mussel, the eastern pearlshell (Margaritifera margaritifera) near the confluence of the Winooski River and the North Branch. Additionally, some sections of the river within the study area have flow and stream bed characteristics that are conducive to macroinvertebrate habitat. The three tributaries within the study area (the North Branch, the Stevens Branch, and the Dog River) have more developed environmental resources and support naturally reproducing populations of brown and rainbow trout, and other various minnow and sucker species.

J. Water Use and Water Quality

Historically, the primary use of water in the Winooski River has been for hydropower at mill sites and hydroelectric facilities such as Green Mountain Power Dam No. 2, Bailey (Clothespin) Dam, Montpelier No. 3 & 4, the Lane Shops Dam, and Wrightsville Reservoir. To this day, hydroelectric power is generated at three dams located within the general study area (Green Mountain Power No. 2, Wrightsville Flood Control Reservoir, and Levesque Dam).

The presence of these and other dams located downstream have limited the navigational and and transportation opportunities. The U.S. Coast Guard has indicated that navigation on the Winooski River extends only 9.5 miles above the mouth with Lake Champlain.

The city does not use the river water as a source of potable water supply. Its supply comes from a reservoir locally referred to as Berlin Pond and from groundwater sources located in upland areas.

The Winooski and North Branch Rivers do serve as an amenity to the City and visitors. Existing recreational paths along sections of the river provide for passive recreation and aesthetics while more paths are being planned. Current in-stream recreational use is limited to fishing and minor canoe activity.

The Winooski River through Montpelier is classified as Class B water by Vermont Water Quality Standards. Class B waters are to be managed to achieve and maintain consistently good aesthetic value and high quality habitat for aquatic biota, fish, and wildlife. There is, however, a waste management zone located at the outfall of the wastewater treatment facility, which is located immediately upstream of the confluence with the Dog River along the left bank.

K. Archaeological and Cultural Resources

An Archaeological Sensitivity Study was performed for the project area during the fall and winter of 1993 by Archaeology Consulting Team, Essex Junction, Vermont. This report determined that there is a moderate to high probability of Native American and European American archaeological sites existing within the project area. Vermont Archaeological Inventory files document three Native American sites in Montpelier, though none are within the project area. However, though there have been few Native American cultural materials recovered, significant archaeological deposits are believed to exist in the floodplain deposits of Montpelier. There are also three known European American sites in Montpelier, one of which is within the project area. This site includes the archaeological materials associated with the Vermont State House, a National Historic Landmark.

III. Flood Risks and Potential Damage

A. Floodplain

The flood plain in Montpelier is depicted in the Flood Insurance Rate Maps (FIRM) produced by the Federal Emergency Management Agency (FEMA) revised February 17, 1982 and in a report completed by the Soil Conservation Service in 1994. The flood plain is divided into two basic zones; Zone A or the 100 year flood plain, and Zone B or the 500 year flood plain. The 100 year flood plain is the area with a 1% chance of flooding in a given year while the 500 year flood plain is the area with a 0.2% chance of flooding in a given year.

The 100 year flood plain encompasses 478.6 acres or 7.2% of the entire city while the 500 year flood plain encompasses 86.5 acres or 1.3% of the entire city. Much of the land surrounding each of the city's four rivers is located within the flood plain. In most areas, the flood plain consists of only a small area on either side of the river; however, in the downtown area near the confluence of the Winooski and North Branch Rivers the floodplain widens considerably. (Figure 3 Flood Plain Map)

B. Property and Structures at Risk

While the combined flood plains comprise only 8.5% of the total area of the city, this small percentage undervalues the impact that the flood plain has on the built environment of the city. The following statistics reveal the importance and impact of the flood plain on Montpelier's built environment:

Property:

Number of properties in Montpelier	=	2794
Number of properties in 100 year flood plain	=	653 (23.4%)
Number of properties in 500 year flood plain	=	95 (3.4%)
Total properties in both flood plains	**=**	**748 (26.8%)**

Structures:

Number of structures in Montpelier	=	3350
Number of structures in 100 year flood plain	=	568 (17%)
Number of structures in 500 year flood plain	=	150 (4.5%
Total structures in both flood plains	**=**	**728 (21.5%)**

Assessed Value (Sept. 97):

Total Assessed Value in Montpelier*	=	409,567,759
Assessed Value in 100 year flood plain*	=	104,968,100 (25.6%)
Assessed Value in 500 year flood plain*	=	47,496,500 (11.6%)

Figure 3 to be available separately.

Total Assessed Value in both flood plains* = 152,464,600 (37.2%)

*Government owned and other tax-exempt properties are represented in these figures.

Table 1. Land Area in Floodplain by Zoning District

Zoning District	Acres in Zoning District	Acres in 100 yr Flood Plain	% in Flood Plain	Acres in 500 yr Flood Plain	% in Flood Plain	Total % in Flood Plain
Low Density Residential (LDR)	3191.73	59.45	1.86%	7.45	0.23%	2.06%
Medium Density Residential (MDR)	2048.83	82.21	4.01	17.17	0.84	4.85
High Density Residential (HDR)	223.23	38.43	17.3	15.57	6.97	24.0
Central Business I (CB-I)	48.81	40.08	82.11	1.10	2.25	84.36
Central Business II (CB-II)	73.67	30.96	42.02	3.8	5.16	47.18
Civic (CIV)	35.42	19.15	54.06	1.62	4.57	58.63
General Business (GB)	320.58	135.64	42.31	23.74	7.41	49.72
Industrial (IND)	172.00	62.44	36.30	13.63	7.92	44.22
Cemetery (CEM)	21.97	--	0.00	0.20	0.91	0.91
Recreation (REC)	184.15	9.10	4.94	0.35	0.19	5.13
Office Park (OP)	275.54	1.16	0.42	1.82	0.66	1.08
Total	**6595.93**	**478.62**		**86.45**		

Source: *City of Montpelier Geographic Information System and property data*

While the total area of both flood plains accounts for only 8.5% of the city its effect on the property, structures and value of the city's real estate is much greater. Nearly 27% of the city's individual properties are at least partially within the flood plain while 21.5% of all of the city's structures are found within the flood plain. More significant is the percentage of the city's total assessed value which is located within this small area of the city. Over 37% of the city's total assessed value is found within the flood plain since most of the city's commercial properties are located in the downtown or along Barre Street or Berlin/River Street, much of which are within the flood plain. This is shown in the breakdown of the flood plain by zoning district which indicates that 51.1% of the city's five commercial zoning districts is within the combined 100 and 500 year flood plain. While no numbers exist to measure the amount of infrastructure that exists in the flood plain, it is considerable compared to the city as a whole since the flood plain encompasses the most developed areas of the city (Table 1).

While the potential damage to be incurred by the city if a major flood happens is significant, the number of property owners who have flood insurance policies is surprisingly low. According to FEMA, of the 653 properties within the 100 year flood plain there are only 224 flood insurance policies for the entire city.. The 224 policies account for $20,302,600 in total flood insurance. The National Flood Insurance Program has paid out a total of $1,520,731 from 12 3 claims.

C. Heart of Montpelier

While the impact of the flood plain is easily assessed in terms of the number of potential structures and properties at risk, it is difficult to assess the emotional impact that a potential flood may have on the city. The key areas of the city, the Capitol Complex and the downtown are located almost entirely within the flood plain. These two areas are the focus of the city's residents and provide the identity of Montpelier. Other important elements of the city found within the flood plain is City Hall and most of the properties on the National Register of Historic Places. Tremendous historic resources are located within the flood plain and are at risk of being damaged in a flood.

IV. Issue Identification

Montpelier has historically been, and is still today, susceptible to two both fluvial and ice jam floods. Both types of flooding have caused enormous amounts of damage to the city and still pose a significant threat. The following descriptions of ice jam and fluvial flooding were taken from the DuBois and King Inc. 1994 Winooski River Flood Control Study.

A. Ice Jam Flooding

Montpelier has always been subject to ice jam floods due to the relatively steep river gradient upstream of the city and the flat gradients downstream. Flood damages have continually increased since the City was initially settled in the 1800s due to development in and around the floodplain. Current development within the floodplain of the city is subjected to inundation, surcharge seepage, and structural damage from ice jams and the resulting increase of the water surface of the river.

In the event of a major ice jam flood the entire downtown area of Montpelier, including the historic business district, and the floodplain throughout the rest of the study area may be inundated depending on the location of the ice jam. As witnessed during the March 1992 event, and also recorded during the 1900 and other historical flood events, multiple areas were flooded as the ice flow moved downstream prior to its final jam location below Bailey Avenue.

Table 2. Summary of Ice Jam Events in Montpelier

Date	Ice Jam Location	Flood/No Flood
February 13, 1900	Cemetery Bend	Flood
February 25, 1915	Langdon Farm, Granite Street Bridge	Flood
March 28, 1917	downstream of Granite Street Bridge and below Cemetery	No Flood
March 26, 1920	Bailey Dam	Flood
January 19, 1929	Granite Street Bridge and below Cemetery Bend	Flood
January 9, 1930	confluence with Dog River and confluence with Steven's Branch	No Flood
January 9, 1935	Baily Dam, below Cemetery, Silver Ledge, Middlesex Dam	Flood
March 16-17, 1936	Cemetery Bend, Middlesex, confluence with Steven's Branch	Flood
December 30, 1948	Main Street Bridge and upstream of Granite Street Bridge	No Flood
March 5, 1964	Main Street Bridge, Middlesex	Flood
December 21, 1973	Bailey Dam	Flood

January 8, 1978	Bailey Avenue Bridge	No Flood
March 18, 1980	vicinity Bailey Avenue Bridge	No Flood
February 12, 1981	Cemetery Bend area	No Flood
March 19, 1986	Cemetery Bend area	No Flood
March 4, 1991	Cemetery Bend area	No Flood
March 11, 1992	Railroad Bridge (briefly), downstream of Bailey Avenue Bridge	Flood

Ice Formation Process

In general, ice formed within the study area is thick, stable ice usually associated with open, slow moving bodies of water. This is because the Winooski River, particularly downstream of Bailey Avenue, has a flat gradient stream bed and low flow velocity. The three dams within the study area (Middlesex, Bailey (Clothespin) and Pioneer dams) create additional reaches of slow moving water, conducive to sheet ice formation.

The ice cover occurs gradually, beginning at the edge of the river as shore ice and extending to the center of the river. The river thalweg, having the fastest velocity, is usually the last section of the river to freeze over. The growth of the sheet ice is generally augmented by frazil ice flows produced in the steeper reaches of the river.

Ice Jam Formation in Montpelier

A detailed evaluation of existing and historical ice jam flooding within the study area has been developed by the Cold Regions and Research Laboratory (CRREL) in Hanover, New Hampshire (1993). The following presents an overview of the report.

The process of ice jam formation can vary with each event. Typical parameters involved in an ice jam include the areal extent, thickness and stability of the ice cover, stream discharge, antecedent rainfall and watershed snow cover, temperature and stream channel characteristics.

In general, ice jams which occur within the Winooski River can be associated with breakup during a mid- to late-winter thaw, although ice-jams have occurred at various times throughout the winter. Typically, ice cover located in the steeper sections of the Winooski, Stevens, and Dog River tributaries will break up and run downstream during or shortly after periods of warm temperatures and rainfall.

Broken ice can lodge against a more stable cover of ice located in the main stem. As previously mentioned, these areas are located behind dams and other areas where flow velocity is slow. In addition, broken ice can lodge against natural or man made constrictions such as river bends, bridge piers/abutments or dams.

The reach from Bailey Avenue bridge to the Dog River, including Cemetery Bend, is the location most susceptible to the formation of ice jams. Approximately 12 of the 17 recorded jams since 1900 have occurred in this reach, particularly around the Cemetery Bend area. The March 1992, ice jam occurred approximately 400 feet downstream of Bailey Ave.

The mechanics of ice jam formation within this area is relatively clear. Unstable, fractured ice enters this area from upstream. The energy available to pass this unstable ice without stalling decreases because of the reduction in energy gradient. The energy gradient reduction results from a decrease in the river bed slope, numerous structures encroaching into the river (wingwalls, etc.), geometries of the stream channel, and backwater conditions downstream. The average slope of the river bed from the toe of Bailey (Clothespin) Dam to the centerline of the Bailey Bridge is approximately 0.0016 feet/foot. The river bed slope from the bridge to the USGS gaging station is approximately 0.0006 feet/foot. (The break in the river bed slope is gradual and does not occur exactly at Bailey Bridge, but rather in the immediate area.) This change in gradient is compounded by the typical presence of a stable, competent cover of ice located in the reach below Bailey Avenue, which is formed by the reduced velocities and shallow depths in the area. As unstable ice flows into the area from upstream, it loses energy from the change in slope, increasing the potential for it to stall.

There are numerous features within the river channel which create hydraulic losses and reduce the energy gradient. These features include bridge abutments and piers (3 bridges are located between Bailey (Clothespin) Dam and Bailey Avenue bridge, one with a center pier), rock outcroppings, significant bends in the river and buildup of sands and gravel shoals.

Backwater from downstream is another factor that can contribute to the decrease in the energy gradient within this area. If high flows are within the Dog River, or if an ice jam forms upstream of the dam in Middlesex, then the potential exists for the river water level to rise below Cemetery Bend and Bailey Bridge. This rising water causes a backwater effect which decreases the energy gradient available to the unstable ice cover.

Any of these factors, usually a combination of each, can cause an ice jam to occur. This appears to be the case with the March 1992 event. According to the USGS Montpelier Ice Jam Flood of 1992 report, the stream data recorded at the USGS gaging station indicated the presence of backwater before the ice jam occurred. The thickness of the ice cover upstream of the gage, measured by the USGS on February 18, 1992, was approximately 1.7 feet.

The North Branch does not appear to contribute significant ice to Winooski River jams although backwater from the Winooski River causes outflow from the the North Branch fairly early in a flood event. The Wrightsville Detention Reservoir located on the North Branch appears to moderate discharge during high runoff events sufficiently to minimize adverse breakup effects.

B. Fluvial Flooding

As mentioned previously , the largest known flood to occur in the State of Vermont, the Great

Flood of 1927, occurred within the study area. As a result of this and other previous flood events, flood control reservoirs were constructed in the watershed of the Winooski River. The purpose of these reservoirs was to provide storage volume and reduce peak flows associated with large magnitude fluvial storm events.

Two flood control reservoirs were constructed within the watershed upstream of the study area; the East Barre reservoir and the Wrightsville Reservoir. These reservoirs provide storage for approximately 38.7 and 68.1 square miles of drainage area, respectively, or approximately 27 percent of the drainage area at the gage in Montpelier, which is approximately 397 square miles. The presence of these two reservoirs has dramatically reduced the effects of fluvial flooding. Since their construction in the 1935, only two significant fluvial floods have occurred neither of which came close to the water levels endured during the 1927 flood. The existence of these two reservoirs has served to reduce the impact of fluvial flooding and has left ice jam flooding as the most important type of flooding to control and mitigate.

C. Flood Damages

The principal problem in the study area is the damage incurred during a flood event, whether caused by ice jam or fluvial events. The damage can be extensive, as witnessed during the March 1992 flood event when inundation of the downtown area resulted in over $5 million in damages.

The types of flood damages are varied. Bridges, water and wastewater facilities, buildings, and other infrastructure can and have been severely damaged by flood waters over the years. Other types of damages are incurred over the long term which include the economic vitality of the city, lost opportunity for investment and development, and the anxiety of property owners, the public school system, and all residents of the area.

The frequency of flood events significantly compounds the principal problem of flood damages. The March 1992 ice jam event has been estimated by CRREL to be a 40-year event. Damages associated with fluvial events are also significant, although the construction of the flood control reservoirs provides for some relief. Out of bank flooding along the North Branch and into the downtown floodplain would occur at less than the 50-year frequency. (Figure 3 Flood Inundation Map)

D. Expected Future Conditions

If no action is taken, the study area will continue to be inundated during severe flood events and incur significant damages. As previously indicated, these damages will not be limited to monetary losses during the event itself, but also long term damages associated with reduced investment and development in the downtown area and undue anxiety for residents of the community.

Figure to be available separately.

Table 3 Flood Stage Elevations for Fluvial Flooding (Open), Ice Jam Flooding (Ice Jam) and Combined Flooding

		Surface Water Elevations														
		2 Year Flood			10 Year Flood			50 Year Flood			100 Year Flood			500 Year Flood		
Reach	River Level	Open	Ice Jam	Comb ined	Open	Ice Jam	Comb ined	Open	Ice Jam	Comb ined	Open	Ice Jam	Comb ined	Open	Ice Jam	Comb ined
1	496.4	513.3	508.3	513.4	516.3	511.5	516.3	519.8	514.0	519.8	521.9	515.0	521.9	526.5	517.3	526.5
2	501.9	515.1	510.0	515.5	518.1	513.1	518.1	521.6	514.6	521.6	523.6	515.6	523.6	528.2	517.0	528.2
3	503.1	516.0	513.6	516.6	519.5	517.1	520.0	523.5	518.8	523.7	525.3	519.5	525.3	529.8	521.0	529.8
4	503.9	516.2	515.0	517.6	519.7	520.3	521.2	524.5	522	524.7	526.7	522.7	526.5	532.3	524.7	532.2
5	504.2	517.0	516.2	518.1	520.4	521.0	521.7	525.7	523.0	526.0	528.3	524.9	528.3	530.4	526.0	534.4
6	515.3	523.0	524.3	525.6	524.9	529.2	529.3	528.4	531.2	531.1	530.8	531.7	532.2	536.5	533.0	536.2
7	515.7	526.4	526.2	527.8	528.8	530.6	530.8	532.0	532.0	532.8	534.3	532.7	534.0	539.8	534.0	539.8
8	517.2	528.7	527.5	529.8	531.1	530.5	531.8	534.6	532.0	534.6	537.5	532.8	537.5	544.4	534.0	544.4
9	524.2	535.7	532.2	535.7	537.5	534.8	537.5	540.5	536.0	540.4	542.1	536.5	542.1	547.5	537.5	547.5
10	522.1	539.0	534.0	539.0	541.0	537.0	541.0	544.8	538.8	544.8	547.0	539.0	547.0	551.7	540.2	551.7

Reach Descriptions:
Reach #1: Extends from the GMP dam in Middlesex to the confluence with the Dog River.
Reach #2: Extends from the Dog River confluence to the Bailey Avenue Bridge.
Reach #3-5: These three reaches extend from the Bailey Avenue Bridge to the Bailey Dam (approximately Main Street Bridge).
Reach #6: Extends from the Bailey Dam to Granite Street.
Reach #7: Extends from Granite Street to the Washington County Railroad Bridge.
Reach #8: Extends from the Railroad Bridge to the Pioneer Dam.
Reach #9: Extends from the Pioneer Dam to the next upstream Washington County Railroad Bridge near the junction of Rts 2 &302
Reach #10: Extends from Rts. 2 & 302 junction to the Rt. 2 bridge near Gallison Hill Road.

Flood damages in the downtown area along State, Elm and Main Streets, and up the North Branch, begin when water reaches an approximate elevation of 519 above sea level (El. 519). At that elevation, basements begin to fill up and damages are incurred. The water level associated with the 10-year fluvial flood event in the area around the Main Street Bridge and the mouth of the North Branch is El. 520.4 and the 10-year ice jam level is El. 523.0. The June 1973 fluvial event had peak water levels in this area of approximately El. 521.5 and is representative of damages which could be expected with a 10-year storm event. Damages during that event included inundation of basements and washouts of local roads.

Extensive damages, similar to the March 11, 1992, flood event, occur when the water level increases to approximately El. 524 and above at the Bailey Dam and at the beginning of the North Branch. The 25-year flood elevation during fluvial conditions is at El. 523.5, the ice jam event is El. 524.8, while the combined flood level is approximately El. 526.0 (Table 2).

E. Death and Injury Caused by Flooding

Montpelier's rivers have claimed at least three lives during this century. Two were drownings unrelated to flooding while one person lost their life during the 1927 flood. While flooding in Montpelier has only claimed one person's life, flooding remains a threat to the safety of Montpelier's residents. Mitigation techniques should strive to eliminate the loss of life and the infliction of injuries due to flooding.

V. Historical Storm Events

There have been many storms and climatological occurrences which have resulted in flooding and flood related damages in Montpelier during the last two hundred years. The following summary of significant Montpelier floods was included in the 1994 Winooski River Flood Control Reconnaissance Study by DuBois and King Inc. using information compiled from various sources, including: old newspaper articles from The Times Argus; a report by Jon C. Denner and Robert O. Brown of the USGS, dated September 1, 1992, Floodplain Information report by the NYDOCOE dated July 1970, and the CRREL Existing/Historical Ice Conditions design interim submittal No. 3, dated February 3, 1994. The following summary of significant floods includes both ice jam and fluvial floods.

July 1830: Fluvial Event

One of the earliest recorded floods within the study area occurred in July 1830. The Winooski River crested at an estimated El. 524.5, resulting in approximately 6.5 feet of flooding in the downtown area. Basements and first floors of buildings were damaged and contents destroyed. Some buildings were completely destroyed as were several bridges on the North Branch. (Flood Plain Information, NYDCOE, July, 1970). This is the second largest known fluvial flood event to have occurred in the study area.

October 1869: Fluvial Event

The Winooski River crested at an estimated El. 522.1, resulting in approximately 4.1 feet of flooding in the downtown area. (Flood Plain Information, NYDCOE, July 1970). This is the third largest known fluvial flood to have occurred in the study area.

February 14, 1900: Ice Jam Event

This event appears to be very similar in nature to the March 11, 1992, event. According to old newspaper articles and recent reports on the 1992 ice jam, rains prior to the flood caused break up of the ice which eventually jammed downstream of Bailey Avenue, near the Green Mount cemetery.

The downtown area of Montpelier, including State, Main, and Elm Streets, was inundated by about 2 feet of water above the street level. Basements in business and residential structures were filled and damage was extensive. Boats were used to transport stranded people from flooded areas.

The flood waters caused extensive damage to structures, buildings, and building contents. Businesses within the downtown area were closed. Ice also jammed against upstream bridges causing extensive damages to at least two bridges when the ice released. The railroad bridge was moved off its bearings and was closed to train traffic until repairs could be made. (Montpelier Argus, Feb. 14, 1900; U.S.G.S. Montpelier Ice Jam Flood of 1992, Sept. 1, 1992)

April 7, 1912: Fluvial Event

The worst flood to occur since the February 1900 ice jam event. According to newspaper reports, the low sections of downtown Montpelier near Main and School Streets were inundated. The Winooski River crested at approximately El. 517.30, with an open water discharge of approximately 17,200 cfs. According to the article "The entire length of Elm Street and Main Street to the foot of Clay hill were under water, while a flood poured down State Street." In addition the article indicates, "…the Winooski River had been diverted and was running down Main Street."

The basements of businesses along Main, Elm and State Streets were flooded resulting in great damages". The newspaper reports that over $25,000 (1912 dollars) of damages were incurred in Montpelier (Montpelier Argus, April 8, 1912).

February 25, 1915: Ice Jam Event

Ice jamming in the river caused water to back up the North Branch and flood basements. The ice crested just below the Langdon Street bridge. Out of bank flooding was reported along Lower State Street and Pioneer Street (U.S.G.S., Montpelier Ice Jam Flood of 1992, Sept. 1, 1992).

November 1927: Fluvial Event

This is the largest flood (fluvial or ice caused) event known to have occurred in recorded flood history in the State of Vermont. A total of 8.6 inches of rain fell over a 38 hour period, beginning late November 2, and finally ending on November 4.

The peak discharge in the Winooski River has been estimated to be approximately 57,000 cubic feet per second (cfs). The maximum water surface level near the confluence with the North Branch was approximately El. 527.0, resulting in a depth of flooding in the downtown area of approximately 8.9 feet. (Flood Plain Information, NYDCOE, July, 1970)

One person lost his life in Montpelier during this flood. The resulting damages included total destruction of homes, businesses, bridges, roads, and automobiles, to list a few. Trees over 250 years old were uprooted and destroyed. The total damages estimated in 1927 were over $3.2 million (The Flood, Montpelier, Vermont, November 3 & 4, 1927).

January 10, 1935: Ice Jam Event

Ice jammed near the Green Mountain Cemetery and at Bailey (Clothespin) Dam. Subsequent high water caused flooding of basements along State, Main and Elm Streets. Another jam occurred near the Granite Street bridge, causing the inundation of Berlin Street.

March 1936: Ice Jam and Fluvial Events

Two flood events occurred; the first was on March 16-17 and was caused by an ice jam at Cemetery Bend. The high water caused localized flooding of the highway toward Middlesex. The Granite Street bridge was threatened by high water and ice. The newspaper article does not indicate if significant damages were incurred.

Continuing rain caused additional flooding between March 18-20. This flood, the largest to have occurred since 1927, had a recorded peak discharge at the Montpelier gauge of 15,600 cfs. The corresponding water surface elevation was El. 516.4. High water caused the flooding of basements and the destruction of contents in buildings adjacent to the North Branch. The water was over the road along Lower State Street and the basements in that area were also flooded. According to the article "The damage in this city and nearby towns was not very extensive. Enough water was held back by the dams at Wrightsville and East Barre so that the flood was kept under control." (Montpelier Argus, March 18&19, 1936, U.S.G.S., Montpelier Ice Jam Flood of 1992, Sept. 1, 1992)

March 4, 1964: Ice Jam Event

An ice jam formed at the Main Street bridge, resulting in high water reaching Rte. 2 and adjacent local roads. Businesses along the North Branch were damaged by flood waters (Cold Regions Research and Engineering Laboratory, Design Interim Submittal No. 3, Feb. 3, 1994).

June 1973: Fluvial Event

According to newspaper reports, this flood was officially declared as the worst flood since 1927. However, no injuries were reported and damage was "…far less than officials had feared". Swollen rivers were almost out of their banks in central portions of the City. At the height of the flood, Montpelier was cut off from the surrounding communities as all roads except Interstate 89 were flooded and closed. Several roads in the City were washed out. A gate on the old Bailey (Clothespin) Dam was blasted in an attempt to reduce the water level behind the dam. Additional damages included the flooding of basements along State, Main and Elm streets, and the subsequent damage and destruction of contents.

Based on predictions made by the U.S. Weather Service, Public Safety officials were fully expecting several feet of water to inundate downtown Montpelier. Officials were surprised when the river began to recede so quickly (Times Argus, July 2, 1973).

January 10, 1978: Ice Jam Event

An ice jam formed near the Bailey Avenue bridge resulting in high water within the Winooski River and North Branch and flooding within the City. The basements in buildings along State and Elm streets were flooded resulting in damages to contents. The water on the North Branch was high enough for the ice to touch the steel stringers on the Langdon Street and Bailey Avenue bridges. At one point, water was up to the axles on automobiles in the low-lying parking lot near the North Branch. A few automobiles parked in this area were damaged. Low lying sections of Lower State Street and Route 2 toward Middlesex were overtopped. Heavy rains also caused extensive ponding of water in certain areas of downtown Montpelier (Times Argus, January 8, 1978, U.S.G.S., Montpelier Ice Jam Flood of 1992, Sept. 1, 1992).

February 12, 1981: Ice Jam Event

An ice jam formed on the Stevens Branch resulting in flooding of highly developed sections of the Barre-Montpelier Road (U.S. 302). Included in this section were a shopping center, a trailer park and local roads. The Vermont Shopping Center was inundated with up to 2 feet of water from the Stevens Branch. People from a local trailer park had to be evacuated. The article indicated that damages may soar into the hundreds of thousands of dollars (Times Argus, February 1 1 & 12, 198 1, U.S.G.S., Montpelier Ice Jam Flood of 1992, Sept. 1, 1992).

March 1992: Ice Jam Event

This is the largest ice jam caused flood event known to have occurred in Montpelier, in terms of the depth of flooding and inundation. Fractured ice stalled approximately 300 feet downstream of the Bailey Avenue bridge, creating a jam and effectively blocking the river channel from conveying the flow of water. Less than one hour after the jam formed, water backed up and overflowed the low point of the river banks in the general vicinity of Langdon Street to School Street on the North Branch. Water depths up to 5 feet covered downtown Montpelier.

The first floor and basements of many buildings were flooded, damaging and/or destroying contents. Numerous automobiles were swept away by the flood waters. Additional damage to buildings and contents included floor slabs in certain buildings, destroyed inventory, machinery, equipment and records, and utilities. Exterior infrastructure damaged included sidewalks, culverts, and a railroad bridge. The 1992 estimated total damages were upwards of $5 million.(Figure 5 Extent of 1992 Flood Inundation)

Researching of city records and anecdotal information indicates that flooding also incurred in the following years: 1782, 1783, 1790-1809, 1810, 1826, 1828, 1842, 1850, 1895, 1901, 1902, 1909, 1914, 1925, and 1928. Detailed information is not known about many of these floods.

Figure 5 to be available separately.

VI. Goals of Flood Hazard Mitigation Plan

The following represent the goals of the flood hazard mitigation plan. These goals are general in nature and the flood mitigation recommendations identified in Chapter VIII are to be used to meet the nine goals outlined below.

1. Reduce the loss of life and injury resulting from flooding.

2. Mitigate financial losses incurred by municipal, residential, industrial, agricultural, and commercial establishments due to flooding.

3. Reduce the damage to public infrastructure resulting from flooding.

4. Reduce the potential for ice jams to occur.

5. Allow the downtown area to continue functioning as a government, business, commercial, and historic district.

6. Improve education and outreach to the community regarding flood hazards and flood mitigation.

7. Increase cooperation among neighboring municipalities to mitigate flood damage.

8. Increase communication among public agencies and the early notification of residents.

9. Ensure that mitigation measures are sympathetic to the natural features of the city's rivers.

VII. Existing City Flood Hazard Mitigation Programs and Initiatives

A. Flood Plain Development Regulations

The City has adopted a Flood Plain District overlay zone that imposes additional requirements above those required by the underlying zoning district as required by the National Flood Insurance Program. The Flood Plain District is based upon the Zone “A” flood hazard areas as designated by the Federal Emergency Management Agency (FEMA) on its Flood Insurance Study for the City of Montpelier dated February 17, 1982. The purpose of this district is to promote health, safety and general welfare, to minimize losses due to flooding, and to prevent the establishment of structures or uses that would either hinder flooding waters or be subject to devastation as a result of flooding.

Through its Zoning and Subdivision regulations, the City requires that all uses and development of land except for agricultural uses, recreational uses, residential open space, and municipal or private parking lots be permitted only upon the granting of a Flood Plain Permit by the Zoning Board of Adjustment. Standards for construction in the Flood Plain District include anchoring structures and other appurtenances properly, using flood resistant materials, locating utilities properly, minimizing infiltration of water and sewer systems, and elevating structures above the flood plain.

Buildings constructed since the City adopted the flood plain standards were not inundated during the 1992 flood. Unfortunately, most of the structures in the city were constructed prior to the flood plain regulations being enacted and were not designed and constructed to withstand significant flooding. Zoning regulations are therefore not a long term solution for flood hazard mitigation but it is recommended that the City continue to enforce and apply the flood plain development regulations.

B. Ice Movement Detection

The City has invested in three ice movement detection units which are frozen into the river each winter. The units are normally placed on the Winooski River near the Pioneer Street dam, on the Dog River, and the Stephens Branch River. The units have been successful in a number of instances of detecting ice movement. When ice movement is detected, the units automatically dial the Police Department at which time personnel are sent to investigate. If ice movement is corroborated then further mitigation measures can be initiated or contemplated.

C. River Watch Program

The River Watch Program was initiated following the 1992 ice jam flood as a means to better monitor the river and its ice cover. Volunteers were trained and given certain sections of the river to monitor and report on any ice movement. This program was successful in providing the City and CRREL with a comprehensive picture of ice formation and movement on the city's rivers. During the last few winters the program has not been necessary due to the mild winters and limited ice formation on the rivers.

D. Ice Deterioration

The City has experimented with a number of mechanical and thermal techniques for ice deterioration. Mechanical techniques include cutting through the ice and the usage of a crane with a steel I-beam to destroy the ice cover. The City has a process in place of cutting through the ice at critical areas to create unstable conditions which will encourage a more orderly ice breakup and allow for the passage of upstream ice. During the last two weeks of February the ice is inspected to determine if ice cutting is warranted. A 4" wide section is cut along both side of the river to disengage the ice from the rock and vegetation along the riverbanks, then chevron shaped cuts are made across the river. The ice is cut from the Bailey Avenue bridge to the Cemetery Bend and is done as many times as necessary to maintain the ice in a weakened state.

Each winter a crane with a steel I-beam is parked near the Cemetery Bend to break-up the ice cover in this area but more importantly to break-up ice jams once they have formed. The Cemetery Bend reach of the Winooski River has been the cause of a majority of the ice jams in the city. The crane was a suggestion of the CRREL 1992 report but its use has not been required since its placement in order to judge its effectiveness.

The City has also experimented with using an excavation vehicle to drive along the riverbed from Bailey Avenue to Cemetery Bend to crush and break up the ice. An access point at the Bailey Avenue bridge has been maintained in the event that a vehicle is needed to break the ice in the future.

The City and CRREL experimented with thermal weakening techniques during the winter of 1992-93. Thermal weakening techniques include the dusting of the ice with dark material to increase the absorption of solar radiation, which in turn weakens the ice cover. The techniques were successful in weakening the ice cover but have not been used since for a number of reasons. The process of preparing the proper type of mulch leaves, storing the material, and finding a suitable machine to spread the leaves has meant this option is not as feasible as other ice weakening options. State permits are required to place material on the ice and this may also be an impediment to incorporating a large scale thermal weakening program if needed in the future. Aesthetically this option is not as desirable since it may require having the dark material on the ice for much of the winter.

E. Emergency Operations Plan

The Emergency Operations Plan includes a supplement for Ice Jam Mitigation which is included in the Department of Public Works section (Annex K). The plan indicates annual readiness efforts which include river watch participation, equipment readiness, and an annual review of key personnel. The plan also includes provisions for pre-ice jam preparedness and ice weakening. A list of telephone numbers for persons involved in the river watch as well as utilities and construction contractors. The Emergency Operations Plan was last updated in June, 1993.

F. Community Rating System

The City has received approval from FEMA to be designated a Level 9 community which is to become effective in October 1998. A rating of 9 will reduce flood insurance rates by 5% for policy holders. The City was granted this reduced rating based upon existing City programs such as participation in the NFIP, mapping of the flood plain, public outreach and education, zoning regulations, and the amount of open space in the flood plain. The City designation will be reviewed by FEMA on an annual basis to ensure the required programs are retained.

F. Results of Flood Plain Survey

The flood plain survey was mailed to all property owners in the flood plain to assess building characteristics in the flood plain, property owner awareness of the flood plain and flood insurance, and property owner interest in financial incentive programs to flood proof their buildings. The response was tremendous with an over 20% return rate. A summary of the survey results is provided on the following page. The summary is indexed by the year the building was built and the building type. In general, the owners of older buildings, which are generally located in the downtown area, are the most concerned about flooding, have taken greater measures to reduce the risk of flood damage and are more interested in grant or loan programs to further reduce the risk of floods damaging their buildings. Furthermore, commercial property owners are much more aware of the risk of flooding, have taken greater steps to prepare for future flooding, and are more interested in grant or loan programs to further reduce the risk of flood damaging their buildings.

Summary of Floodplain Survey Results

February 5, 1998

Year Built/ Building Type	Are Utilities Located In Basement?		Are Fuel Tanks Not Anchored to the Ground?			Were You Aware Your Property is in the Floodplain?		Are You Aware of Any Past Flood Damage?		Do You Consider Flooding to be a Threat to Your Property?			Do You Presently Have a Flood Insurance Policy?		Are You Aware That Flood Insurance is Available and Often Required?		Would You be Interested in a Grant Program To Floodproof Your Home or Building?			Would You be Interested in a Low Interest Loan Program?		
	Yes	No	Yes	No	Don't Know	Yes	No	Yes	No	Yes	No	Don't Know	Yes	No	Yes	No	Yes	No	Maybe	Yes	No	Maybe
1800-1850 (n=8)	7 87%	1 12%	5 62%	3 38%	0 0%	6 75%	2 25%	4 50%	4 50%	3 37%	3 37%	2 25%	4 50%	4 50%	6 75%	2 25%	4 50%	0 0%	4 50%	1 12%	2 25%	5 62%
1850-1900 (n=53)	51 98%	1 2%	25 47%	26 49%	2 4%	45 86%	7 14%	41 79%	11 21%	38 72%	13 24%	2 4%	33 61%	21 39%	51 96%	2 4%	29 56%	6 12%	16 32%	17 33%	11 21%	24 46%
1900-1950 (n=30)	27 90%	3 10%	17 57%	10 33%	3 10%	22 76%	7 24%	17 57%	13 43%	19 63%	8 27%	3 10%	14 50%	14 50%	23 79%	6 21%	13 48%	6 22%	9 30%	6 21%	12 43%	10 36%
1950-1998 (n=16)	9 56%	7 44%	7 44%	9 56%	0 0%	13 81%	3 19%	2 12%	14 88%	4 25%	9 56%	3 19%	4 25%	12 75%	15 94%	1 6%	3 19%	9 56%	4 25%	1 6%	9 56%	4 38%
Total (n=107)	95 89%	12 11%	54 51%	46 44%	5 5%	86 82%	19 18%	64 60%	42 40%	64 60%	33 31%	10 9%	55 52%	51 48%	95 90%	11 10%	49 48%	21 20%	33 32%	25 24%	34 33%	43 43%
Residential (n=58)	55 95%	3 5%	43 75%	10 19%	4 6%	41 71%	17 29%	24 41%	34 59%	24 40%	28 47%	8 13%	20 35%	38 65%	48 83%	10 17%	21 37%	13 23%	22 40%	4 7%	20 35%	33 58%
Commercial (n=49)	40 85%	7 15%	13 23%	33 70%	1 7%	47 100 %	0 0%	41 87%	6 13%	40 85%	6 13%	1 2%	34 72%	13 28%	46 98%	1 2%	20 53%	7 18%	11 29%	21 45%	15 32%	11 23%

VIII. Flood Mitigation Recommendations

The flood mitigation recommendations are presented in the following section and are divided into various categories. Within each category the mitigation recommendations are prioritized as being of "High", "Medium", or "Low" priority. Information regarding which agencies will be responsible for implementation, the resources available, and the time frame for the recommendations to be implemented will be given for all of the mitigation recommendations. The available resources refer to both financial and informational resources.

A. Early Warning and Emergency Response

1. *Reorganize the River Watch Program*. High Priority
   Who: City of Montpelier
   When: Short term

2. *Work to increase volunteer citizen participation in the River Watch Program*. High Priority
   Who: City of Montpelier
   When: Short term

3. *Increase ice jam and ice movement detection training for River Watch volunteers and city officials*. High Priority. Following the 1992 flood during the formation of the River Watch program, volunteers were trained by CRREL and Montpelier Emergency Management personnel to properly report, log, and detect ice movement.
   Who: City of Montpelier, CRREL
   When: Short term
   Resources Available: CRREL, FEMA

4. *Continue the placement of ice movement detection units on the ice at important locations*. High Priority
   Who: City of Montpelier
   When: Existing program which should be continued.

5. *Establish a yearly meeting of city and other officials to prepare and coordinate emergency responses to flooding*. High Priority. For several years following the 1992 flood, officials met during the winter for the Ice Jam Reunion to coordinate flood prevention measures and emergency procedures. City officials meet each winter to discuss the ice jam situation but this could be expanded to once again include federal and state officials.
   Who: City of Montpelier, State Buildings and General Services Department, Vermont Emergency Management, FEMA
   When: Short term

6. *Increase number of ice movement detection units and upgrade existing units*. Medium Priority
   Who: City of Montpelier, CRREL
   When: Long term

7. *Increase residents' awareness of the proper emergency procedures to follow during a flood*. Medium Priority
   Who: City of Montpelier
   When: Long term
   Resources Available: City of Montpelier Police and Fire Departments, Federal Emergency Management Agency, Institute for Home and Business Safety

8. *Continue to work with utilities to ensure their assistance in controlling hazardous situations which may arise during a flood*. Low Priority
   Who: City of Montpelier, Green Mountain Power, Central Vermont Public Service Corporation, fuel service companies
   When: Long term

9. *Lobby for the continued and/or increased funding of the USGS river stream gauges*. Low Priority
   Who: City of Montpelier, United States Geological Survey
   When: Long term

10. *Encourage the use of the National Weather Service's NOAA weather radios among the general public*. Low Priority
    Who: City of Montpelier, National Weather Service
    When: Long term

B. Building and Property Improvements

1. *Provide assistance to property owners to dry flood proof their buildings*. High Priority
   This assistance could be in the form of grant money, loans, or technical assistance. The survey sent to flood plain property owners showed that over 50% of commercial properties owners and 37% of residential property owners would be interested in grant programs to flood proof their homes or buildings. 45% of commercial property owners would also be interested in low interest loan programs to flood proof their buildings. Dry flood proofing techniques consist of upgrading the building to not allow water to enter.
   Who: City of Montpelier, State Labor and Industry, Vermont Emergency Management, FEMA
   When: Short term
   Resources Available: FEMA Flood Hazard Mitigation Assistance Program Project

Grant, Institute for Home and Business Safety, FEMA retrofitting and flood proofing library

2. *Provide assistance to property owners to wet floodproof their buildings*. High Priority. Wet flood proofing techniques allow water to enter into a building but balances the hydrostatic pressure to reduce damage to the building. Wet flood proofing is often not appropriate for older buildings since their foundations and general construction cannot withstand an increase in hydrostatic pressure; however, this form of flood proofing may still be appropriate for newer buildngs.
   Who: City of Montpelier, State Labor and Industry, Vermont Emergency Management, FEMA
   When: Short term
   Resources Available: FEMA Flood Hazard Mitigation Assistance Program Project Grant, Institute for Home and Business Safety, FEMA retrofitting and flood proofing library

3. *Encourage the proper anchoring and venting of fuel tanks to avoid contamination and injuries from floating tanks*. High Priority. An estimated 8,000 gallons of fuel oil was discharged into the floodwater during the 1992 flood. Much of the oil was washed downstream, however, a large amount was left behind in basements, storm sewer drains, streets, and grassed areas. The residue of this discharged fuel presents environmental concerns as well as public health and safety risks. Many reports were also received of smaller tanks floating in the flood waters which can pose a significant safety hazard.
   Who: City of Montpelier, Vermont Emergency Management, fuel service companies
   When: Short term
   Resources Available: FEMA Flood Hazard Mitigation Assistance Program Project Grant

4. *Encourage property owners to install utilities in the first floor or above the floodplain*. High Priority
   Who: City of Montpelier, State Labor and Industry
   When: Long term
   Resources Available: FEMA Flood Hazard Mitigation Assistance Program Project Grant

5. *Elevate buildings above the 100 year flood plain level*. High Priority
   Who: City of Montpelier, Vermont Emergency Management
   When: Short term
   Resources Available: FEMA Flood Hazard Mitigation Assistance Program Project Grant

6. *Encourage owners of historic properties to implement appropriate mitigation measures*

to reduce or prevent damage from flooding. Medium Priority
Who: City of Montpelier, State Division of Historic Preservation
When: Medium term and ongoing
Resources Available: FEMA Flood Hazard Mitigation Assistance Program Project Grant, State Division of Historic Preservation

7. *All actions taken to repair structures following a flood should consider the historic nature of the structures and area*. Medium Priority
Who: City of Montpelier, State Division of Historic Preservation
When: Medium term and ongoing

C. Public Awareness and Education

1. *Increase participation in and awareness of the NFIP homeowner insurance program*. High Priority. There are currently only 224 flood insurance policies in the city. According to the survey results, 72% of commercial property owners carry flood insurance but only 35% of residential property owners have flood insurance. This correlates with property owner views on the threat of flooding to their property where 85% of commercial property owners considered flooding to be a significant threat to their properties while only 40% of residential property owners considered flooding to be a significant threat to their properties. Also, nearly all commercial property owners were aware that flood insurance is available but only 83% of residential property owners were aware that flood insurance is available. The City has begun to increase awareness of the availability and need for flood insurance through the Community Rating System requirements.
Who: City of Montpelier, FEMA
When: Presently being done and should be continued and improved upon.
Resources Available: City of Montpelier, FEMA

2. *Increase education and awareness of residents regarding the history of flooding in Montpelier, safety procedures to follow during flooding, and the existing size and extent of the flood plain*. Medium Priority. The City has begun this process through the Community Rating System requirements but public awareness programs should still be increased by distributing materials through area banks, targeting mailings, and so on.
Who: City of Montpelier
When: Existing program which should be continued and improved upon.
Resources Available: City of Montpelier, FEMA

3. *Educate residents and property owners regarding the most effective way to clean up after a flood*. Medium Priority. Many health problems can occur from not allowing a building to properly dry out following a flood and flooding may also present other hazards such as broken glass and the distribution of hazardous materials. The City has begun to educate residents about this through the Community Rating System

requirements.
Who: City of Montpelier, FEMA
When: Existing program which should be continued and improved upon. Should also be intensified following a flood event.
Resources Available: City of Montpelier, FEMA

4. *Provide information and implement a workshop for insurance professionals, property owners, merchants, and community leaders to explain the costs and benefits of the National Flood Insurance Program (NFIP).* Medium Priority
Who: City of Montpelier, FEMA
When: Medium term
Resources Available: City of Montpelier, FEMA

D. Protection of Product Inventory and Records

1. *Encourage businesses and offices to develop a system of duplicate records with one set to be stored off-site in a secure area.* Low Priority
Who: City of Montpelier, Montpelier Merchants Association
When: Long term

2. *The storage of materials in the basements of buildings should be discouraged.* Low Priority. Much of the damage caused by the 1992 flood included damage to records and other materials stored in the basement of commercial buildings.
Who: City of Montpelier, Montpelier Merchants Association
When: Long term

E. Municipal Programs, Activities and Mitigation Measures

1. *The crane situated at Cemetery Bend during the winter months should be continued.* High Priority. One of the outcomes of the review of the 1992 ice jam flood was the placement of a large crane with an I-beam attached which could break up the ice near the Cemetery Bend which is the most vulnerable area for ice jams to occur.
Who: City of Montpelier
When: Existing program which should be continued.
Resources Available: City of Montpelier

2. *Ice cutting should be continued based on monitoring of the ice cover situation.* High Priority. The cutting of the river ice has been shown to weaken the ice cover in the ice jam risk area below the Bailey Avenue Bridge.
Who: City of Montpelier
When: Existing program which should be continued.
Resources Available: City of Montpelier

3. *Continue the City's participation in the National Flood Insurance Program (NFIP) and the issuing of Flood Plain Permits for development in the flood plain.* High Priority. The Flood Plain Development Regulations in the Zoning and Subdivision Regulations have been very successful in ensuring new construction is built to proper flood proofing standards. Structures built following the initiation of these regulations were spared from significant damage during the 1992 flood.
   Who: City of Montpelier, Vermont Emergency Management
   When: Existing program which should be continued.
   Resources Available: City of Montpelier, Vermont Emergency Management, FEMA

4. *The City should continue to seek alternate locations outside of the rivers for snow dumping and storage.* Medium Priority. The practice of dumping snow in the rivers may reduce the hydraulic capacity of the rivers, not only due to the snow, but also the sand and debris carried with it. The piles of snow may also compress, and large chunks break off, blocking narrow parts of the river channels.
   Who: City of Montpelier
   When: Existing policy which should be continued

5. *Continue to maintain thermal weakening techniques as an available option to reduce ice thickness and ice cover.* Medium Priority. The thermal weakening of the ice was shown to work during the winter of 1992-93 however questions remain regarding the amount of labor required, the availability of State permits, and the availability of suitable storage area for the material.
   Who: City of Montpelier
   When: Medium term
   Resources Available: City of Montpelier, CRREL, State Water Quality Division

6. *State permits should be pursued in order to allow the dusting of the ice with dark material to weaken the ice through thermal weakening.* Medium Priority
   Who: City of Montpelier, State Water Quality Division
   When: Medium term

7. *The City should establish a procedure for direct communication with the operator of the facility at the Wrightsville Dam for the purpose of reducing discharge during a future ice jam.* Medium Priority. This dam controls approximately 17% of the total drainage area above the Montpelier USGS gauge. The actual water level cannot be directly controlled; however, the turbines can be shut off which could potentially reduce the level of water by up to a half foot. Even if jams form, reduced discharge will lower water levels and thus prevent or reduce potential flooding. Water transit time from the Wrightsville reservoir to Montpelier is approximately 2 hours which would provide enough time to cause a reduction in the water level of an ice jam.
   Who: City of Montpelier, Green Mountain Power
   When: Short term

8. *The city should establish a procedure for direct communication with the operator of the facilities at the East Barre Dam, Molly's Falls Pond, Levesque Hydroelectric dam, and Worcester for the purpose of improving the early warning system for fluvial floods.* Medium Priority. These dams are automatically monitored off-site at central locations by their operators. A system could be implemented that the Montpelier Police Department is automatically contacted in the event that water levels exceed a certain height at the various stations in order to provide city officials with an early indication of rising water levels.
Who: City of Montpelier, Green Mountain Power
When: Medium term

9. *Continue to participate in the Community Rating System.* Medium Priority. Pursue a lower rating for the City to further reduce flood insurance rates for the city's property owners.
Who: City of Montpelier, FEMA
When: Existing program which should be continued.
Resources Available: City of Montpelier, FEMA Community Rating System program

10. *Consider the advantages of municipal buildings being floodproofed.* Many of the City's municipal buildings are presently located in the flood plain including the Fire Station and City Hall. Proper arrangements should be made to ensure the maintenance of emergency services during a flood. Low Priority
Who: City of Montpelier
When: Long term and when new and expanded facilities are warranted.

11. *Pursue funding of a "Self-insurance Disaster Fund" to alleviate the economic hardship felt by the city following a disaster.* Low Priority
Who: City of Montpelier
When: Low Priority
Resources Available: City of Montpelier

12. *Explore utilizing waste heat from the City's waste water treatment plant to melt or weaken ice that forms downstream of Bailey Avenue.* Low Priority. CRREL recommended diverting the discharge pipe approximately 50 feet upstream to prevent anchor ice from forming beneath the I-89 bridge. Due to slope gradient requirements for the plant's intake and discharge pipes, this option may prove costly.
Who: City of Montpelier, CRREL
When: Long term

F. Open Space

1. *Encourage the preservation of existing open space in the floodplain.* Approximately 25

acres of open space presently exists in the floodplain which is made-up mostly of the Elm Street Recreation Field, Green Mountain Cemetery, Montpelier High School playing fields, and the Statehouse lawn. Medium Priority.
Who: City of Montpelier
When: Long term and during the planning stages of City and State projects which seek to reduce the amount of open space in the flood plain.

G. Ice Retention Structures

1. *Explore the feasibility of modifying the Bailey and Pioneer Dams to retain break-up ice runs by installing piers above the dam crests*. Low Priority. The piers would restrain movement of the ice cover that forms on the pool above the dam. As water levels rise during the break-up period, the ice cover rises on the piers and water flows under the cover and over the dam crest. Retaining ice covers above these two dams could increase the chances of initiating ice jams upstream of Montpelier.
Who: City of Montpelier, CRREL, State Water Quality Division
When: Long term
Resources Available: CRREL, FEMA

2. *Consult with CRREL regarding other innovative structures which could potentially retain break-up ice runs*. Low Priority. CRREL has been testing other ice retention structures such as wire-mesh booms, trusses, and boulder lines during the years since their initial report following the 1992 flood. These new innovations should be reviewed for their suitability in helping to reduce the potential for ice jam formation in Montpelier.
Who: City of Montpelier, CRREL
When: Long term

3. *Explore the feasibility of installing a tension weir to control the production of frazil ice along the steep river section above the Route 2/302 intersection*. Low Priority. The weir develops a small pool in the river in which an ice boom collects frazil ice to form an ice cover. One of the causes of ice jams is frazil ice moving downstream and becoming lodged in slower moving portions of the river.
Who: City of Montpelier, CRREL, State Water Quality Division
When: Long term
Resources Available: CRREL

H. Removal of Buildings and Hazards

1. *Buildings which pose a hazard to public safety should be removed from the floodplain either through relocation, elevation, or demolition*. High Priority
Who: City of Montpelier, State Labor and Industry
When: To be considered when a building is declared unsafe in the flood plain.

Resources Available: FEMA Flood Hazard Mitigation Assistance Program Project Grant

2. *Study the area of the Winooski River from the Bailey Avenue bridge to Cemetery Bend to determine if dredging or the removal of islands/impediments would be beneficial.* High Priority. This reach of the river is very susceptible to ice jams and there are many features of the river which may increase the severity of ice jams in this reach. Specifically, a large island has formed down river of the bridge which may serve to block ice moving down river. It may be beneficial to either remove or reduce this island in size.
Who: City of Montpelier, State Water Quality Division, CRREL
When: Short term
Resources Available: City of Montpelier, State Water Quality Division, CRREL, Army Corps of Engineers, FEMA Flood Hazard Mitigation Assistane Program Project Grant

3. *Remove hazards, impediments, and other debris from the rivers and riverbanks.* Medium Priority. Often debris such as large trees can impede the normal flow of water and act as a dam where ice can become jammed. Montpelier's rivers also contain many man-made structures which are no longer in use which pose a significant hazard by restricting the natural flow of water. When no longer in use these structures should be removed and the river returned to its natural state.
Who: City of Montpelier, State Water Quality Division
When: Short term
Resources Available: FEMA Flood Hazard Mitigation Assistance Program Project Grant, City of Montpelier, State Water Quality Division

I. Flood Hazard Mitigation Options Not Included in this Plan

Through previous studies of Montpelier's flooding situation and initial reviews of this plan, a number of mitigation options were suggested which have not been included in this plan. While these mitigation options may seem viable on initial inspection, each contain significant flaws and potential negative impacts which have led to their not being included in the final recommendations of this plan.

<u>Channel Modifications and Dredging</u>
Modifying the Winooski River channel geometry and slope was investigated for the DuBois and King Study (1994). Because of the frequency of ice jams in the reach from Bailey Avenue to the Dog River, this reach was evaluated to determine if channel hydraulic characteristics could be improved enough to reduce potential flood levels associated with ice jams. The evaluation was based upon attempting to maximize the slope of the river to increase the energy gradient and reduce the potential for fractured ice to stall. Widening the river channel was also included in the analysis. The results of the analysis indicated that the upstream water surface

during ice jam conditions similar to the March 1992 event would be reduced by less than one foot through these measures.

Dredging and other channel modifications pose other concerns to the river itself and the potential for ice jams. According to CRREL, the main effect of dredging a river is that the river's velocity is slowed. This slower velocity has a number of negative outcomes. First, fine particles carried by the river are more apt to be deposited in areas of the river which have a slower velocity which means that this dredged section of the river would quickly fill back in. Therefore dredging has a very short term life and would need to be done often to maintain any benefits. Second, it has been shown on other rivers that slowing a river's velocity actually worsens the effects of an ice jam since the ice jam is stopped due to the lower water level and the slower river velocity. Ice jams are alleviated by "floating-out" the ice jam. With a lower water level and lower water velocity, ice jams cannot be "floated-out" as easily and frazil ice moving downriver more readily collects behind the jam therefore worsening the effects of the jam. The slower the velocity of the river, the more difficult it becomes to "float-out" an ice jam.

Negative effects to the river itself can include increased bank instability, bank erosion, and riverbed erosion. Removing natural impediments such as islands and sand bars is not suggested as a mitigation option since the impediments would quickly build up again since the cause of the impediments would be still present. According to the State Water Quality Division, obtaining the necessary permits to dredge the Winooski River would be difficult to obtain based upon the existing information regarding the effect of dredging on ice jam alleviation.

<u>Diversion Channels</u>

This was studied in the DuBois and King Inc. Study (1994) for the Army Corps of Engineers. The following is a summary of the description and findings from that study.

Ideally a new dry bypass channel would be located such that the inlet was upstream of the head of the ice jam, within an open water reach. The outlet would be located downstream of the toe of the ice jam with a free discharge capacity. A diversion channel which would reduce the potential for inundation in the downtown area would need to extend over 6,500 feet from below the Cemetery Bend to above Granite Street.

The high density development in and around the flood plain prevents any reasonable feasibility of constructing a diversion channel of this magnitude. The high costs of constructing both open channel and buried flow structures, combined with utility relocation and construction through the railroad bed and traveled roads, and also the potentially significant impacts to environmental and cultural resources, eliminates this alternative from further evaluation.

Due to the relatively high frequency of ice jams occurring in the reach between Bailey Avenue and the Cemetery Bend, an analysis was performed to determine if a bypass channel to divert the Winooski River around this area would be beneficial. The results of the analysis indicate that the water level of an ice jam would be reduced by approximately 0.5-1.0 feet assuming that the bypass channel is not blocked with snow or ice and that water is able to freely enter the inlet to the channel. Because of the minimal reduction in the ice jam water level this option was not considered further.

Flood Walls and Dikes

The DuBois and King Inc. Study (1994) concluded that constructing a flood wall along the right bank of the Winooski River from the confluence with the North Branch to the railroad bridge and then extending it up both sides of the North Branch to the Lane Shops dam was a feasible option. The purpose of the flood wall is to reduce the potential for inundation of the downtown by raising the banks of the North Branch, preventing them from being overtopped as water in the Winooski River backs up the North Branch during flood events. The top of the wall was proposed to be set at an elevation of 529.5 feet which provides protection from a 100 year flood event. The wall was proposed to be constructed with reinforced concrete, impervious earthen materials, dry laid up stone, or architectural panels while the walls of buildings abutting the river would need to be dry flood proofed.

The construction of a flood wall is not being included in this plan due to practical and aesthetic concerns. Concerns remain about how the numerous bridges which span the North Branch would be dealt with since having walls is not useful if the bridges provide an outlet for the water to circumvent the heightened walls. Some sort of gate system would need to be incorporated which would not be feasible for aesthetic and practical reasons. The public and city officials have also raised concerns with the appearance of a wall extending through the downtown which would obscure the river and be readily noticeable from many streets and buildings.

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