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Technical Bulletin - Special Flooding Hazard Conditions in River and Stream Systems

Ministry of Natural Resources

Ontario

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List of Acronyms

CA	Conservation authority
CDA	Canadian Dam Association
FPL	Flood protection landform
HPC	Hazard potential classification
IDF	Inflow design flood
MECP	Ministry of Environment Conservation and Parks
MNR	Ministry of Natural Resources
OFCF	Offline flood control facility
PPS	Provincial Planning Statement

1 Introduction

This technical bulletin provides guidance on:

- When and how flood mitigation structures are to be considered in flood hazard modelling and mapping, including dams, dykes, berms, flood walls and flood protection landforms.
- How other special flood hazard scenarios should be modelled and mapped.

The technical bulletin should be read in conjunction with the natural hazard policies of the Provincial Planning Statement (PPS) and the *Technical Guide: River and Stream Systems: Flooding Hazard Limit,* which provides detailed guidance on the flood related inundation of areas adjacent to river, stream and small inland lake systems.

This technical bulletin is provincial guidance issued under the PPS. Information, technical criteria and approaches outlined in this document are intended to support implementation of the PPS but to not add to or detract from the policies in the PPS. Unless explicitly stated otherwise, terms in this document have the same meaning as in the PPS.

2 Background

Flood mitigation structures include any artificial structure that could have a flood mitigation effect and include dams and reservoirs, stormwater management facilities, dykes, berms and flood walls and flood protection landforms.

While flood mitigation structures can reduce the risk of flooding, they cannot eliminate it. The construction of flood mitigation structures can result in increases to upstream flood levels and downstream flows and velocities, thereby creating new or aggravating existing flooding hazards in conflict with the general policies for natural and human-made hazards contained within the PPS. Flood mitigation structures can be prone to failure depending on the magnitude and nature of the flood event, or due to complicating factors such as ice jams or sedimentation. Poor design or lack of maintenance can further increase the risk of failure. Failure can lead to fast water level rise and high flow velocities caused by rapid breach outflow, inundating development behind these structures. They can lull communities into a false sense of security that they are protected from flooding, and are always at risk of being improperly designed, constructed or located and inadequately monitored and maintained. Flood mitigation measures are also associated with high costs during construction and in perpetuity afterwards. New construction adds to the existing municipal infrastructure deficit and the ongoing costs associated with the operation, inspection, maintenance and repair may be unaffordable for some municipalities.

The province continues to promote prevention and non-structural approaches to flood mitigation, including land use planning and permitting as the most cost-effective way to protect people and property from flooding hazards.

While prevention-based approaches have been shown to be more effective in reducing the impacts of flooding and as a result limiting the exposure of people and property to risk, the Province has empowered municipalities to assume responsibilities for the identification and management of flood hazards; provided that decisions affecting planning matters are consistent with the PPS. Development pressures, including provincially mandated targets for increased densification and infill development are increasingly placing additional pressure on planning authorities to utilize currently undeveloped areas in existing settlement areas, including areas historically located in the flood plain. As a result, planning authorities are increasingly exploring opportunities to account for the effects of flood mitigation structures when modelling and mapping the flooding hazard.

The sections below provide guidance on minimum recommended requirements that should be met prior to accounting for the effects of any flood mitigation structures when modelling and mapping the flooding hazard. Where these recommended requirements have been met, sufficient rationale may exist to consider accounting for the effects of flood mitigation structures modelling and mapping the flooding hazard.

The recommended requirements set out in this Technical Bulletin are not intended to be a list of mandatory instructions to be rigidly applied in all circumstances or to replace best professional engineering judgement when undertaking site-specific flood hazard analyses. Rather it serves to assist technical staff experienced in water resources in ensuring an appropriate level of caution, particularly when uncertainty is present, has been taken to justify accounting for the effects of flood mitigation structures in flood hazard modelling and mapping activities. An appropriate level of conservatism should be carefully considered to balance the need to protect people and property with the desire to minimize the potential for excessive costs and unnecessarily prohibitive measures. While acknowledging that complete certainty in predicting details relating to flooding is impossible, an appropriate level of conservatism is recommended, which means including reasonable safety factors and considering worst-case scenarios where warranted. This approach acknowledges that a range of factors may lead to engineered structures not consistently functioning as designed, for a range of reasons including as a result of unforeseen events. This includes applying an appropriately protective or appropriately conservative approach to the way that various components are factored into flood hazard modelling and ultimately flood hazard mapping that informs where development may occur.

The need to apply professional engineering judgement when undertaking site-specific flood hazard analysis should not be misconstrued as authority to disregard the minimum recommended requirements outlined within this Technical Bulletin. Planning authorities and decision-makers are expected to demonstrate that the recommended requirements were reviewed, considered, and used to inform their decisions. Any departures from these recommended requirements should be noted within the resulting technical report and supported by clear documentation demonstrating that reasonable grounds for the departure to exist.

3 Standards for considering flood mitigation structures

Flood mitigation structures can moderate flood risk downstream, but they do not eliminate the risk. The primary purpose of these structures is to alleviate flooding impacts to development.

However, there may be situations where it can be appropriate to consider flood mitigation structures when modelling and mapping the flooding hazard, subject to specific requirements. These requirements are intended to confirm that the structures are expected to function as anticipated during extreme storm events, are at a low risk of failure, and can reasonably be expected to be maintained in perpetuity. Stepwise evaluation of the recommended requirements outlined within this Technical Bulletin may lead decision makers to exclude structures originally designed to reduce flood flows or mitigate the impacts of development.

Where recommended requirements are met and it is determined that accounting for the effects of flood mitigation structures may be appropriate, a range of flow management approaches are available for modelling the flooding hazard, including using:

- Unmitigated: Modelling without consideration of flood mitigation structures (generally recommended).
- Partially mitigated: Modelling with consideration of part of the effects of flood mitigation structures.

- Mitigated: Modelling with consideration of the effects of flood mitigation structures (least conservative).

Decisions regarding the appropriateness of incorporating the effects of flood mitigation structures into flood hazard modelling and mapping should be carefully assessed by a professional engineer to ensure that doing so does not present unacceptable risks to public health or safety or property damage. Any residual risks associated with the inclusion of flood mitigation structures into flood hazard modelling and mapping should be disclosed to local decision-makers, emergency management services, and the public.

3.1 Artificial storage structures

Artificial storage on the landscape includes dams, associated reservoirs and stormwater management facilities which have the potential to affect peak flows of the flooding hazard.

For artificial storage to be considered in hydrologic and hydraulic modelling, and integrated into mapping of the flooding hazard, it is recommended that facilities meet the requirements in Appendix 1 – Recommended requirements for consideration of OFCFs in hazard modelling or Appendix 2 – Recommended requirements for consideration of existing flood control dams in flood hazard mapping.

This section describes the process for considering artificial storage structures and the potential impacts to the extent of the mapped flooding hazard.

3.1.1 Stormwater management facilities

3.1.1.1 Traditional stormwater management ponds

Traditional stormwater management ponds (i.e. designed to a 2-100 – year storm), should not be considered when modelling and mapping the flooding hazard. These facilities are intended to help manage urban run-off and mitigate localized flooding and are not specifically designed, constructed, equipped or maintained to store the volume of rainfall and associated runoff during a storm that defines the flooding hazard in Ontario. During large flood events, traditional stormwater management ponds cannot be assumed to behave as designed, particularly if the limited storage capacity associated with these facilities is partially full.

3.1.1.2 Offline Flood Control Facilities

In contrast, Offline Flood Control Facilities (OFCFs) can store significantly larger volumes of water than traditional stormwater management ponds, up to or exceeding the flooding hazard. OFCFs are increasingly being constructed in some areas to help reduce flood flows and resulting flood hazard limits. As a relatively new practice in Ontario, the risks associated with relying on OFCFs for flood mitigation are largely unknown and there are no provincially approved design standards governing their construction, operation or maintenance.

The Ministry does not recommend considering OFCFs when modelling flood hazard limits where concerns exist regarding the:

- risk of structural failure;
- risk of storms exceeding design capacity or profile, or occurring when facility is not operating at maximum capacity;
- reduced capacity over time due to sedimentation or debris build up;
- uncertainty of long-term funding and maintenance.

Consideration should only be given to considering OFCFs in modelling where they meet the specific requirements in Appendix 1 – Recommended requirements for consideration of OFCFs in hazard modelling. Where these recommended requirements have been met, it may be appropriate to consider modelling the flooding hazard downstream of an OFCF using a mitigated or partially mitigated flow.

3.1.2 Dams and reservoirs

In most cases, using the unmitigated flow to identify the flooding hazard downstream of a dam is the recommended approach. However, where public safety is the primary issue, and supported by the hazard potential classification (HPC) of the dam, the recommended option is to use peak flows resulting from failure.

Using mitigated flows based on the operation of the dam is not recommended since:

- Funds to maintain and replace the structure in perpetuity cannot be assured
- Projected peak flood attenuation may not be achieved as a result of:

- ice, debris or sediment accumulation that affect storage
- operating problems that alter discharge capacity
- floods that vary from the design event in terms of timing, volume and hydrograph shape.

However, in the limited circumstances where these are not relevant to a specific dam, and subject to the recommended requirements in Appendix 2 – Recommended requirements for consideration of existing flood control dams in flood hazard mapping, it may be appropriate to model and map the flooding hazard downstream of a dam using a mitigated or partially mitigated flow. These recommended requirements are intended to ensure that a dam is purpose-built for flood mitigation and maintained in perpetuity, such that mapping a reduced flooding hazard will not increase risk to public health, safety or property. In taking this approach, practitioners should consider:

- potential for increases to the dam's HPC associated with future development
- how the inflow design flood (IDF) of the dam compares to the flooding hazard.

Historical context can be considered when determining the most appropriate flow management approach. For example, in the rare event that mitigated flood flows have been used historically, this may have influenced the design capacity of downstream structures such as bridges, dykes, floodwalls and flood channels. It remains necessary to evaluate how risks associated with the dam may have changed given increasing knowledge, new risks such as climate change, and continued or intensified development in flood plain areas.

In all cases, if a mitigated or partially mitigated flow is used, a dam break analysis should be conducted to determine the maximum flooding hazard downstream of the facility.

For additional details concerning dam management in Ontario, please consult the *Lakes and Rivers Improvement Act* and associated dam management technical bulletins.

3.2 River adjacent flood mitigation structures

River adjacent flood mitigation structures are constructed to prevent flood water movement beyond the stream corridor and are intended to prevent floodwaters from reaching and inundating areas behind these structures. These include:

- linear barriers such as earthen embankments (i.e., dykes or berms)
- flood walls
- flood protection landforms.

This section provides guidance on when it may be appropriate to consider these structures in delineating the flooding hazard.

3.2.1 Dykes, berms and flood walls

Dykes, berms and floodwalls may act to hold back water during a flood, but few have been purposefully designed, constructed and maintained to hold back or contain the flooding hazard.

These structures should only be considered in flood hazard mapping where they meet the recommended requirements in Appendix 3 – Recommended requirements for inclusion of dykes, berms and floodwalls when mapping flood hazards. This includes structures that:

- Are designed and constructed in a robust manner for the purpose of flood protection.
- Meet or exceed the relevant flooding hazard level.
- Are properly maintained and monitored in perpetuity.

This would generally discount existing or legacy structures on a range of factors, however legacy structures that serve a flood mitigation role for historic and existing development can be considered in specific circumstances. This will require additional engineering, including geotechnical study of the legacy structure to confirm it is technically sound in its ability to safely hold back water during the flooding hazard event. In addition to technical capabilities, confirmation will be required that the structures maintenance and asset management plans are in place to clearly demonstrate its long-term viability.

3.2.1.1 Considering failure in modelling dykes, berms and floodwalls

All floodwalls, dykes and berms are prone to failure. Modes of failure can include overtopping from floods that exceed the design elevation, erosion, seepage, and settlement (subsidence). Poor design or lack of maintenance can further increase the risk of failure. Failure can lead to fast water level rise and high flow velocities caused by rapid breach outflow, inundating development behind these structures.

It is recommended that dyke, berm and flood wall breach analyses be undertaken to determine the flooding hazard limit, ascertain information on flood propagation and damage assessment.

3.2.2 Flood Protection Landforms

A flood protection landform (FPL) is generally defined as a flood mitigation measure made of earth and having a clay core that may provide an enhanced level of flood protection. FPLs are similar to berms and dykes, since they are constructed barriers placed adjacent to river corridors to provide passive protection from flooding. Unlike traditional dykes, berms and flood walls however, landforms are built on a much larger scale with very gentle slopes. This translates to FPLs having a significantly larger footprint, which can limit their application due to the land area required to meet crest width and wet side and dry side gentle slope criteria. Landforms are designed to generally require less maintenance and provide a significantly higher level of protection in terms of typical modes of failure. In a risk-based decision-making system, FPLs allow for many risks associated with flooding to be substantially reduced.

Recent evidence has shown that some municipalities are considering the use of FPLs to open areas up to new or intensified development and their use may have a role to play in certain situations where the value of increased development can justify their expense and offset lost opportunity costs because of their vastly larger space requirements.

FPLs can be considered in modelling and mapping the flooding hazard, however, the scale of FPLs and the risks associated with failure means that each FPL requires specific design consideration based on local geography, geology, hydraulics and other considerations. Specific design criteria include among other things, crest width, core material composition, wet-side slope as well as dry side slope and materials. Deviation from those criteria precludes the flood mitigation structure being referred to as an FPL. Despite being robust to many modes of failure, FPLs remain sensitive to overtopping, during flood events exceeding the flooding hazard standard.

4 Mapping the influence of flood mitigation structures

Flood hazard mapping is intended to transparently communicate risk to the public and support municipalities in directing development away from high-risk areas. Reducing risk to public health, to safety, or of property damage remains the priority.

When mapping the flooding hazard, there are 2 approaches available:

- Single-line approach, where:
    - the flooding hazard mapping identifies the unmitigated flow (generally recommended); or
    - the flooding hazard mapping identifies the mitigated flow (least protective)
- Two-line approach, where the flooding hazard mapping identifies the mitigated flow, and the unmitigated flow on the same map using the two-zone concept.

4.1 Single-line approach

The recommended approach to mapping is to map a single line that represents the unmitigated flow. This is the most conservative approach and clearly communicates the expected maximum risk area to the community.

While generally not recommended, in some circumstances, where doing so will not present unacceptable risks to public health, safety or property, it may be appropriate to map the mitigated flow with a single line.

Any significant variation between the unmitigated and mitigated flow should be documented in associated hydrology and hydraulic study reports, where not included in official flooding hazard maps. To provide greater clarity in communicating flood risk to communities, this variation should also be shared with local decision-makers, emergency service provides and the public.

4.1.1 Flood protection landforms

A mitigated single-line approach can be used behind FPLs that have been appropriately designed based on local conditions, including local geography, geology, hydraulics and other considerations.

Due to the significantly more extensive design criteria, including assessment of various failure methods, storage credit for FPLs can be considered, and areas on the dry side of the structure would not require additional floodproofing. However, mapping of the residual risk on the dry side of the FPL should be completed to assure that residents, and emergency management services have an appreciation of the residual risks that exist, in the event of failure or overtopping.

4.2 Two-line approach

A two-line approach allows both the mitigated and unmitigated flooding hazard to be illustrated on the flood hazard map. The two-line approach provides similar benefits to mapping only the mitigated flow, while highlighting the maximum expected flooding hazard if mitigation structures do not function as expected during a specific flooding event.

To minimize complexity, if two lines are used on flood hazard maps, the line used to demarcate the unmitigated flooding hazard should be shown in a heavier line weight to make it clear to the public reading the map the limit of flooding hazard.

Where a two-line approach is used, the two-zone concept should be applied, consistent with the technical and safety criteria, with the area between the two lines identified as flood fringe.

4.2.1 Artificial storage structures

A two-line approach identifies both the mitigated and unmitigated flooding hazard where upstream storage structures meet the relevant requirements in Appendix 1 – Recommended requirements for consideration of OFCFs in hazard modelling or Appendix 2 – Recommended requirements for consideration of existing flood control dams in flood hazard mapping. This approach also illustrates the flooding hazard if upstream purpose-built flood storage were not available to manage a flooding hazard event, or if a flood larger than the flooding hazard occurred and flood management storage was exhausted.

4.2.2 River adjacent flood mitigation structures

Similarly, a two-line approach can be used behind dykes, berms and floodwalls if they meet the requirements in Appendix 3 – Recommended requirements for inclusion of dykes, berms and floodwalls when mapping flood hazards. This shows the benefits of the flood mitigation structure and identifies the flooding hazard if the structure is not able to protect against a specific flood event.

Where a structure meets these requirements, the floodway can be considered contained within the structure area. The area behind the structure can be considered as flood fringe.

The flood elevation behind the dyke, berm or floodwall would be the increased flooding hazard elevation contained by the dyke, berm or floodwall. The flooding hazard mapped behind the structure should identify the area as flood fringe and inform the elevation that floodproofing would be required.

Any new development would continue to require floodproofing to the increased water surface elevation resulting from the structure containing the flooding hazard. If new development in the flood fringe cannot be floodproofed to the flooding hazard, then special policy area status may be requested, subject to the appropriate requirements. This approach acknowledges that while some of the flood risk has been alleviated, a residual risk of flooding remains behind the structure.

The establishment of no development or limited development zones behind a dyke will be dependent on local conditions (i.e., flood depth and velocity) and local approaches to flood hazard management. Certain areas immediately behind a dyke may be considered too hazardous for any use or some types of use if failure of the dyke was ever to occur. In addition to this, the area immediately behind the dyke will be required for maintenance purposes, as per access standards and protection works standards for flooding hazards.

Construction of these flood mitigation structures may result in an increase in flood levels at the site and along upstream and downstream reaches of the river. Any observed or modelled increase in flood levels must not create new or aggravate existing flood hazards. To assess this potential, detailed hydraulic modelling must be undertaken at a satisfactory distance upstream, downstream and at the structure to discern the effect on the flooding hazards relative to inundation under existing conditions, including effects on associated flood depths and velocities.

4.2.3 Multiple flood mitigation structures in the same location

Where the influence of multiple flood mitigation structures coincide, flooding hazard mapping should remain limited to 2 lines representing the mitigated flooding hazard and the unmitigated flooding hazard. In some circumstances (for example, a dyke and upstream OFCFstorage), this means that the influence of only a single structure is considered in mapping the flooding hazard. This avoids complexity associated with identifying the flooding hazard by 3 or more lines and provides greater clarity in communicating flood risk to communities. It is recommended that the most conservative unmitigated and mitigated lines be mapped where appropriate.

5 Further considerations in flood hazard mapping

5.1 Bridges and culverts

Bridges and culverts are primarily designed based on economic considerations. Roadway crossings are not intended to act as dams although the design often must accommodate temporary ponding behind the structure. This could increase the flooding hazard upstream and reduce it downstream.

Any changes to these types of structures will lead to changes to temporary backwater ponding, potentially reducing or eliminating it, as well as changing the flooding hazard both upstream and downstream.

When mapping the flooding hazard around bridges and culverts, the following assumptions are recommended:

- Upstream flood mapping should make allowance for the backwater affects caused by the structures.
- Downstream flood mapping should use the natural flood line to delineate the flood hazard, making no allowance for the temporary upstream ponding.

Where these assumptions result in unacceptable conditions, the culvert should be replaced, or alternatively, where feasible, the two-zone concept should be introduced as described in the *Technical Guide – River and Stream Systems: Flooding Hazard Limit*. Under the two-zone concept, minor filling would be permitted in shallow areas provided the filling would create no adverse flooding including creating new or aggravating existing flooding hazards or environmental impacts upstream or downstream.

For large embankments, steady state hydraulic modelling may overestimate upstream flood elevations. In these circumstances, further consideration of storage effects and flood routing analysis may be required. The *Technical Guide – River and Stream Systems: Flooding Hazard Limit* provides additional recommendations on modelling around bridges and culverts.

5.2 Flood spills

Modelling of spills using 2D modelling can provide better understanding of the dynamics of spills than 1D modeling. This is especially true of the resulting extent of the flooding hazard limit, both along the primary watercourse and in the area of the spill. In some cases, the area flooded by spills is extensive. This has led to the need for guidance regarding regulation of the flooding hazard in spill areas and the mapping of potential spill areas if structural measures such as dykes, floodwalls or road grading has been implemented to limit or contain spills.

Detailed analyses are required to understand the complex hydraulics associated with a spill. Modelling a flood spill may progress from an initial steady state 1D approach that identifies the spill, to a full unsteady state 2D hydraulic analysis to confirm the spill extent and sufficient volume in the flood hydrograph and spill hydrograph to flood the predicted areas.

5.2.1 Structures containing flood spills

The preferred method of managing flood spills is to increase channel conveyance to remove the potential for spills from the flooding hazard limit. In some circumstances, increasing conveyance may not be feasible, practical or justifiable. Containment using a low elevation berm, dyke, floodwall or road grade design may be an alternative measure to manage the flood spill hazard where the spill is confirmed to include a low percentage of the flood flow volume.

Structures used to contain flood spills such as low elevation dykes, berms and floodwalls or road grade designs should be considered in the same way as structures managing the flooding hazard limit. These structures can contain flood spills that would otherwise randomly leave the flooding hazard limit at one point and rejoin the flood plain or leave the watercourses watershed, entirely.

If structural measures to address flood spills have been properly designed and constructed (to the flooding hazard standard plus freeboard) to contain the spill hazard, and it is demonstrated the structural measures will be maintained and inspected in perpetuity, then the likelihood of a flood spill hazard has been reduced. Management of flood spill areas should be treated separately from flooding hazard areas through the use of a separate designation from the normal flooding hazard but continue to address flood spills as hazardous lands under the PPS.

5.2.2 Uncontained spills

For uncontained spills, depending on the severity and frequency the spill and its delineated pathway, it may be appropriate to map the spill with the flooding hazard associated with the watercourse.

6 Glossary

Flood mitigation structures: include any artificial structure that could have a flood mitigation effect, whether or not it is purpose built, or the primary purpose of the structure is flood mitigation. This includes:

- Dams and reservoirs
- Dykes, berms and floodwalls
- Flood protection landforms
- Stormwater management facilities

Hazard potential classification (HPC): categorizes dams according to the potential hazards presented by the dam. The hazard potential is determined through an assessment of the greatest incremental losses that could result from an uncontrolled release of the reservoir due ot the failure of a dam or its appurtenances. Potential incremental losses are to be assessed with respect to life, property, the environment and cultural - built heritage sites at the dam site, upstream, downstream, or at other areas influenced by the dam.

Purpose Built: A structure or facility specifically designed, constructed, equipped and maintained to serve a particular flood mitigation purpose, including a robust monitoring and maintenance program to ensure the facility continues to work as designed in perpetuity under the range of circumstances it is anticipated to experience over its design life. This includes integral adaptive management protocols to support modifying the structure or facility should monitoring or maintenance efforts, new science or evidential data identify that modifications are required for the facility or structure to continue to meet its intended purpose.

Mitigated flooding hazard: The flooding hazard with consideration of all flood mitigation structures that meet the relevant criteria for inclusion.

Unmitigated flooding hazard: The flooding hazard with no consideration of the benefits of flood mitigation structures.

7 References

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8 Appendix 1 – Recommended requirements for consideration of OFCFs in hazard modelling

The following outlines recommended requirements to support inclusion of existing or new Offline Flood Control Facilities for use in reducing downstream flows in new/updated flood hazard modelling and mapping.

If an Offline Flood Control Facility cannot be shown to meet the required criteria and provide the necessary documentation, its influence on flooding and the associated flooding hazard limit should not be considered.

Documentation should be included in the technical report supporting the flood hazard mapping that outlines whether facilities meet or not meet these criteria.

Table 1 General requirements for consideration of Offline Flood Control Facilities in flood hazard mapping

#	Recommended Requirement
1.	The facility must meet all relevant requirements for environmental permissions and comply with specifications under Environmental Compliance Approvals issued by the Ministry of Environment Conservation and Parks, as well as applicable municipal guidance and standards.
2.	The facility must be recommended as part of a comprehensive flood study, a watershed or subwatershed plan, and include endorsement by municipal council resolution.
3.	The facility is municipally/publicly owned and maintained.

#	Recommended Requirement
4.	The facility must be located outside the flooding hazard limit and flood plain.
5.	The facility must be passive (i.e., no pumped storage industrial control systems to enable storage), and furthermore: a) Rooftop and parking lot storage, as well as infiltration, shall not be considered. b) Underground containment or storage of storm sewerage, in detention tanks or by other means, shall not be considered.
6.	For new facilities, construction is to be supervised by a qualified Engineer/Engineers, who shall provide signed and sealed as-built drawings and written confirmation that the facility has been constructed in accordance with the approved design and documentation of any site-specific directions provided by the Engineer. This shall also include sign-off from a qualified Geotechnical Engineer.

Table 2 Flood attenuation design recommendations for consideration of Offline Flood Control Facilities in flood hazard mapping

#	Recommended Requirement
1.	Design volumes and discharge rates for the facility are defined and set to ensure that existing downstream peak flood flows are maintained for the flooding hazard, and this has included: a) An iterative design process to appropriately adjust storage volumes and discharge curves to optimize the design. b) An assessment of hydrograph timing and magnitude effects beyond the catchment of interest has been completed for all key downstream nodes to a point where the area controlled by the facility is less than 10% of the total drainage area at that point. This included an assessment of detained runoff peaks and the coincident timing of flood peaks and associated impacts on downstream peak flood magnitudes under the flooding hazard standard.

2.	The feature was designed and constructed to provide quantity control to regulate the flooding hazard associated with the water course where flood hazard mapping is being updated: a) Where the facility was designed and constructed to control Ontario's storm-based flooding hazard event standards (i.e. Hurricane Hazel and/or Timmins storm) or other approved standard that exceeds the 100-year flood, the facility shall posses fail safe features including, but not limited to, an emergency spillway. The emergency spillway shall be designed to safely pass flood flows exceeding the storm-based flooding hazard standards, away from the facility, which, at a minimum, would correspond to the unmitigated flood peak flow under the flooding hazard event, up to and including the probable maximum flood (PMF), as appropriate, to allow the facility to release water during extreme floods. For this purpose, a continuous outlet path is present to the receiving watercourse, and this path must be sufficient and satisfactory to convey the unmitigated flow under the flooding hazard condition. Lands associated with this outlet conveyance pathway must be in public ownership. b) Where the facility was designed specifically to control both the one-hundred-year flood and the storm-based flooding hazard standard, controls may be considered within the 1:100-year and storm-based flooding hazard modelling, as per design and relative to the specific event producing the largest flood. c) Where the facility was designed to control exclusively the 1:100-year flood, controls may be considered within the 1:100-year flood event only. d) In areas where the flooding hazard event standard is the 1:100 – year flood, the design storm duration and volume used to establish the 1:100 – yr flood hazard mapping flows should carefully consider storm duration and volume to appropriately test the storage features effectiveness.

Table 3 Structural design recommendations for consideration of Offline Flood Control Facilities in flood hazard mapping

#	Recommended Requirement
1.	The facility should exist as primarily an excavation below native ground elevation. Where embankments are required to be constructed, embankment heights should not exceed a recommended 0.5m in height.
2.	The facility must include a minimum freeboard above the maximum water level of the facility under the flooding hazard event standard. This freeboard shall accommodate a reduction in available flood storage within the facility due to the occurrence of multiple storm events over a short period, referred to as storm event stacking. Minimum freeboard requirements shall follow standard practices relative to the fetch length of the facility (e.g., MNR, 2011c).
3.	Where embankment heights exceed 0.5m, a hazard potential classification of the embankment structure of the facility be undertaken using a technique analogous to those employed for embankment dams (e.g., MNR, 2011a).

#	Recommended Requirement
4.	All facilities must meet industry standard requirements for geotechnical design and factors of safety for earthen embankment type structures and structures on overburden foundations. For embankments exceeding 0.5 m this also includes, but is not limited to the following: a) Geotechnical engineering design and analyses shall be performed to demonstrate that the facility, its foundation and abutments will remain stable under all hazards and loading conditions. Geotechnical hazards for earthen embankments may include seepage (internal erosion, piping and hydraulic fracturing), deformation (consolidation, slope instability static and dynamic liquefaction) and surface erosion. Loading conditions include: i) end of construction (dead load; pore pressures and uplift) ii) state-state conditions (operations) iii) rapid pond surcharge and drawdown iv) wind and wave action v) earthquake. b) Industry accepted factors of safety must be adhered to for loading conditions identified in item 4(a), taking into account the reliability of inputs to the stability analysis, the probability of the loading condition and the losses of the potential failure in relation to embankment slope stability, involving a static assessment and seismic assessment be undertaken. Additional loading conditions considered shall include long-term (steady state seepage for wet ponds), design flood loading condition, rapid surcharge, pseudo-static. Suitable factors of safety can be found in (MNR, 2011b) or related standard best management practices (e.g., Canadian Dam Association (CDA), 2016).

#	Recommended Requirement
5.	Sufficient documentation exists to verify the facility's outlet structure, design rating curve and function under anticipated conditions. Impacts of potential over-topping, flow bypass, tailwater impacts, and any other relevant considertations on the facility's function must be considered and documented. Confirmation the facility can manage the flooding hazard standard safely and as originally designed, including under emergencies exceeding the unmitigated flooding hazard standard flood magnitude.

Table 4 Operation, maintenance and surveillance recommendations for consideration of Offline Flood Control Facilities in flood hazard mapping

#	Recommended Requirement
1.	Surveillance, inspection and maintenance programs are in place that meet or exceed industry standards (e.g., CDA, 2013; CDA, 2016)) to ensure timely maintenance and replacement of the facility, in perpetuity. Inspections are undertaken following all major flood events to check for damage and ready the facility for future events.
2.	An asset management plan including on-going funding commitments is in place to support the surveillance, inspection and maintenance programs.
3.	Consideration of potential volume reduction through sedimentation through site investigation and documentation. This may be particularly important in dry-ponds.

Table 5 Verification and corroboration recommendations for consideration of Offline Flood Control Facilities in flood hazard mapping

#	Recommended Requirement
1.	Signoff from the operating municipality including the municipality's lead engineer, identifying that the municipality will continue to maintain the facility for the benefit of downstream property owners (signed confirmation) or proof of endorsement of the plan recommending the facility be accepted and considered to attenuate flood flows under the flooding hazard and be relied upon in the establishment of flooding hazard limits (i.e., flood lines) and the municipality's commitment to long term maintenance of the facility.
2.	Documentation is required to be provided based on a site investigation and characterisation by a professional engineer that demonstrates through an investigation of the above criteria, there are no anticipated concerns with the facility's performance (i.e., no erosion, blockage, failure concerns etc.) and the facility is expected to function during large storms as well as the flooding hazard event standard, as designed, and constructed, subject to additional assessment/model refinements arising from the current study.
3.	Confirmation from the flood hazard mapping study's Engineer that the storage facility is appropriate for inclusion in the flood hazard modelling, and this confirmation being explicitly provided in the flood hazard modelling and mapping report.
4.	Clear identification of the specific facilities that were used to attenuate the flooding hazard in the technical report supporting the flood hazard mapping.

#	Recommended Requirement
5.	Clear documentation of the mitigated and unmitigated flood flows and elevations under the flooding hazard condition, to support comparison of the relative difference in flood magnitudes. This shall be reported in tabular format and reported for all flow nodes and included within the technical report supporting the flood hazard mapping.

9 Appendix 2 – Recommended requirements for consideration of existing flood control dams in flood hazard mapping

The following outlines recommended requirements to support inclusion of existing flood control dams to reduce downstream flows in new/updated flood hazard modelling and mapping. If a dam cannot be shown to meet all the criteria in Table 6, its impact on peak flood flows under the flooding hazard should not be considered within flood hazard mapping.

Table 6 Recommended requirements for consideration of existing flood control dams

#	Recommended Requirement
1.	Is an existing dam that has been previously granted written acknowledgement regarding its role in contributing to mitigated flood flows downstream, for the purposes of flood hazard mapping.
2.	Dam was part of a flood mitigation strategy or watershed plan or master stormwater plan that used a comprehensive watershed approach to mitigate flooding to existing downstream development in the flooding hazard limit. This can include documentation and referencing in the flood hazard mapping report of historic flood mitigation studies recommending use of the storage facility.
3.	Dam must be identified in the CA operational plan for water control infrastructure required under Section 5 of Ontario Regulation 686/21 if part of the flood management infrastructure and flow regulation system of a larger river or watercourse system owned and operated by a CA.

4.	The facility or structure be purpose built for flood flow attenuation, complete with fail safe features including, but not limited to an emergency spillway designed to the probable maximum flood (PMF) allowing the facility to release water during extreme floods exceeding the flooding hazard.
5.	Regular inspections are completed at minimum annually and following major flow events.
6.	Is owned and maintained by the municipality or CA.
7.	Has an asset management plan and funding in place to fund long term and ongoing maintenance.
8.	Is designated in official plans as a flood control/flood mitigation dam, drawing from information in planning documents or watershed plan documents, and unique and separate from non-flood-control dams. Designation in official plans is to ensure recognition of the facility is addressed and has continuity.
9.	If the facility requires operation during floods, it has a reservoir operating policy, plan, trained staff and is in compliance with the provincial *Lakes and Rivers Improvement Act* technical bulletins where the facility is designated as a dam under the *Lakes and Rivers Improvement Act*. This includes confirmation that staff are fully trained and capable of responding to the operational requirements of the facility during a flood. Integration of reservoir operations with flood forecasting and flood warnings to downstream affected areas.
10.	A dam safety and management program delivered by the dam owner with an emergency preparedness plan for each dam.

11.	Clear identification of which dams were used to produce mitigated flow (i.e., reduced flooding hazard) in the technical report supporting the flood hazard mapping.
12.	Clear documentation of the mitigated flows and the unmitigated flood flows under the flooding hazard, to support comparison of the relative difference in magnitude in tabular format for each transect or flow node.

10 Appendix 3 – Recommended requirements for inclusion of dykes, berms and floodwalls when mapping flood hazards

The following outlines the recommended requirements to support inclusion of dykes, berms and floodwalls designed to the flooding hazard in new and updated flood hazard mapping.

A series of requirements must be met to allow consideration of purpose-built structures in defining flooding hazard limits. These requirements are to demonstrate that river adjacent flood mitigation structures are expected to function as anticipated during extreme storm events, are at a low risk of failure, and can reasonably be expected to function and be maintained in perpetuity. The evaluation of these requirements may lead to the exclusion of facilities originally designed for flood mitigation purposes.

Table 7 Requirements for inclusion of dykes, berms and floodwalls when mapping flood hazards

#	Recommended Requirement
1.	Dyke, berm or floodwall design was part of an overall comprehensive flood mitigation plan with a recommended design capacity.
2.	Comprehensive engineering and geotechnical investigations were completed and detailed design reports and drawings are available for the dyke, berm and floodwall works.
3.	Drawing(s) detailing the design capacity and design elevations of the flood mitigation works are available.

#	Recommended Requirement
4.	Detailed surveying, engineering and geotechnical analyses to confirm that existing, or 'as-is' conditions correspond to the design and 'as built' conditions.
5.	Detailed hydraulic modeling studies have been completed to verify the actual design capacity of the dyke, berm and floodwalls based on detail hydraulic model calibration to observed flood elevations.
6.	Confirmation that removal of flood plain storage in the area behind the dyke, berm or floodwall has neglible or no increase the upstream or downstream flood hazard.
7.	Confirmation that implementing the dyke, berm or floodwall: does not increase upstream flood elevations to existing development in the flood plain, or increases upstream flood elevations by less than 0.1 metres, and does not aggravate existing flooding hazards or create new hazards where they weren't previously observed under the flooding hazard.
8.	River adjacent flood mitigation structures are in public ownership or have easement agreements on title to facilitate access for inspection and maintenance, and as per *access standards* and *protection works* standards in the PPS.
9.	An asset management plan and funding is in place to fund long term and ongoing maintenance of the mitigation works.

#	Recommended Requirement
10.	For flood mitigation structures owned and maintained by a conservation authority, Ontario Regulation 686/21: Mandatory Programs and Services, under the *Conservation Authorities Act*, requires an operational plan and an asset management plan for the dyke, berm or floodwall asset.
11.	Operational response plans are in place for flood mitigation works requiring operations during a flood. (e.g., temporary bridge closure, stop logs, closure of isolation valves for storm drainage works, temporary pumping of storm drainage).
12.	Physical testing of operational flood mitigation works on an annual basis or regular basis. (e.g., temporary stoplog closure of bridges)
13.	Inspection of flood mitigation structures on annual basis as a minimum and following major events during which flood mitigations works were active or flood waters were in contact with the base or toe of structure.
14.	Level monitoring of the hydraulic profile is in place at various locations along the dyke or floodwall works to facilitate verification and calibration of hydraulic modelling used to estimate mitigation works capacity.
15.	A framework and protocol for documenting any disturbances to the dyke or floodwall resulting from construction or utility placement or installation. Procedure for restoration and inspection of the disturbed flood works to confirm structural integrity following disturbance.
16.	Ongoing diary recording disturbances to dyke, berm or floodwall.

#	Recommended Requirement
17.	Independent safety review studies of the flood mitigation structure with a maximum recommended period of 5 years between reviews.