Guidelines for Invasive Investigation Plans & Instrumentation Records

BC Dam Safety Program

Ministry of Water, Land and Resource Stewardship

Version 0.0

May 2024

The Dam Safety Program is releasing this document in draft form. If you have any feedback please direct it to dam.safety@gov.bc.ca

Contents

1. Acronyms

BC	the province of British Columbia.
CDA	Canadian Dam Association
HRPAW	High-Risk Professional Activities or Work
DEP	Dam Emergency Plan
DSO	Dam Safety Officer
EGBC	Engineers and Geoscientist BC
FERC	Federal Energy Regulatory Commission
FEMA	Federal Emergency Management Agency
HRPAW	High-Risk Professional Activities or Work
IR	Instrumentation Record
IIP	Invasive Investigation Plan
IICR	Invasive Investigation Completion Report
IDSRMP	Interim Dam Safety Risk Management Plan
OMS	Operation, Maintenance and Surveillance Manual
USACE	U.S. Army Corps of Engineers
USBR	U.S. Bureau of Reclamation

2. Definitions

Canadian Dam Association (CDA) publishes technical guidelines on dam safety that are considered good established practice.

Dam as defined in the Dam Safety Regulation, means

> (a) a barrier constructed for the purpose of enabling the storage or diversion of water diverted from a stream or an aquifer, or both, and
>
> (b) other works that are incidental to or necessary for the barrier described in paragraph (a).

Dam Emergency Plan (DEP) a record prepared by the dam owner describing the actions to be taken by the owner if there is an emergency at the dam, and containing information for use by the local emergency authorities. The plan must be submitted to a dam safety officer for acceptance.

Dam Safety Officer (DSO) means a statutory decision maker designated under the *Water Sustainability Act*. The DSO has regulatory authority for acceptance of an Invasive Investigation Plan or Instrumentation Record.

Engineers and Geoscientist BC (EGBC) regulates and governs professional engineers and geoscientists in BC. Publishes technical and quality management guidelines that are considered good established practice.

Federal Energy Regulatory Commission (FERC) publishes technical guidelines on dam safety that are considered good established practice.

Federal Emergency Management Agency (FEMA) publishes technical guidelines on dam safety that are considered good established practice.

Heave colloquial term used in drilling. Describes a condition where soil flows into a drill borehole casing, because the water pressure in the surrounding soils is higher than in the borehole. This disturbs the surrounding soil, which may create a void leading to internal erosion and potentially cause dam failure.

High-Risk Professional Activities or Work (HRPAW) means activities or work that involves the potential for significant consequences.

Hydraulic fracture is a condition caused by drilling that may occur in cohesive material in embankment dams and foundations. This occurs when the water pressure in the borehole is higher than the surrounding soil, resulting in a pressure imbalance causing the cohesive material to form a crack. In a dam, this may destabilize the structure, initiate internal erosion processes, and potentially cause dam failure.

Instrumentation Record (IR), as defined by the Dam Safety Regulation, is a written record describing any proposed installation, modification, replacement or removal of an instrument associated with a dam. In this guideline, the requirements for an Instrumentation Record would also apply to the annual instrumentation plan described in Section 19 (2) (b) of the Dam Safety Regulation.

Invasive Investigation involves drilling, trenching, test pit excavation and other activities involved in an invasive investigation within a dam or near a dam. The purpose of an invasive investigation may include collecting subsurface data to address data gaps in construction documentation, confirm construction records, install instrumentation, decommission instrumentation, collect soil or rock samples for construction planning, evaluate vegetation impacts, or other purposes.

Invasive Investigation Plan (IIP) the combination of 1) an authenticated technical plan prepared by the Professional of Record describing the proposed invasive activities at a dam, and 2) an Interim Dam Safety Risk Management Plan prepared and authenticated by a qualified professional. As required by the Dam Safety Regulation this plan must be submitted to, and accepted by a Dam Safety officer before an invasive investigation may begin.

Invasive Investigation Completion Report (IICR) means a report summarizing the results of the invasive investigation.

Interim Dam Safety Risk Management Plan (IDSRMP) is a plan prepared by a qualified professional, created for use during an invasive investigation. The purpose of the plan is to identify failure modes and hazards that may be caused by the work, as well as enhanced surveillance or changing operational procedures to mitigate the risks. The plan should also identify equipment and supplies to have available during the work.

Non-Destructive Investigation is the determination of the subsurface material properties and distribution in a dam or foundation using surface measurements and empirical relations. Typically requires specialized equipment and sensing devices.

Operation, Maintenance and Surveillance Manual (OMS) – a manual, prepared by the dam owner, that describes the operation, maintenance and surveillance procedures for the dam. The manual must be submitted to a dam safety officer for acceptance.

On-Site Supervisor means a professional engineer who is in the field full time, actively observing and documenting the invasive investigation work, and directing the equipment operator or drillers. The Professional of Record may also fulfill the role of On-site Supervisor.

Professional of Record means an individual qualified professional who is responsible for preparing the submitted Invasive Investigation Plan, overall supervision of the work, and reporting of the works. They are expected to authenticate the Invasive Investigation Plan (IIP) technical plan, and Invasive Investigation Completion Report (IICR).

Qualified Professional for an invasive investigation into a dam means a person with experience and training in dam safety, analysis and design, and is registered with Engineers and Geoscientists BC (EGBC).

Risk Assessment means a documented process involving, 1) identifying hazards 2) evaluating the identified hazards based on severity and likelihood of the consequences to determine a risk level, and 3) comparing the risk level to risk tolerance criteria.

Sinkhole is a cavity that forms in a dam embankment. A sinkhole may form because of internal erosion processes, including concentrated leak, contact erosion, suffusion, or erosion into open joints in the foundation or into a conduit.

Test Hole for an invasive investigation, a term to describe a borehole, trench, cone penetration test (CPT), dynamic penetration test (DPT), test pit, hand dug hole or hand auger hole.

U.S. Army Corps of Engineers (USACE) publishes technical guidelines on dam safety that are considered good established practice.

U.S. Bureau of Reclamation (USBR) publishes technical guidelines on dam safety that are considered good established practice.

3. Introduction

The purpose of this guideline is to assist dam owners and qualified professionals in preparing an invasive investigation plan (IIP), or instrumentation record that meets the requirements for acceptance by the BC Dam Safety Program. The BC Dam Safety Program has authority to apply the Dam Safety Regulation to all regulated dams licensed in BC under the Water Sustainability Act. The Dam Safety Regulation includes Section 16 – Invasive Investigations, and Section 19 – Instrumentation, both of which require a plan or record to be submitted to a dam safety officer for acceptance, prior to the work commencing. This guideline defines the form and content for submission of the IIP or instrumentation record, requirements for field work, and requirements for reporting after the work.

This guideline was largely written considering embankment dams and foundations. However, the general concept and good established practice of planning the work in consideration of failure modes, executing the work in a manner to minimize risk, and reporting the findings so another qualified professional can use the data, is applicable to all dam structures. To be clear, invasive activities that are subject to this guideline include, but are not limited to:

- Drilling, sampling and testing
- Excavation including trenching, test pits, hand dug pits, hand augers, etc.
- Concrete coring
- Installing subsurface instrumentation including piezometers, standpipes, inclinometers, shape arrays, thermistors, seismometers, etc.

Invasive investigations into dams can be a high-risk activity and should not be undertaken unless necessary and all other non-destructive methods have been considered. The potential risk must always be weighed against the need for the information. Due to the inherent risk, the Dam Safety Regulation requires that a dam owner ensures that all invasive investigation activities must be directly supervised by an engineering professional who has qualifications and experience in dam design, construction and analysis.

The process for planning an invasive investigation involves a dam owner procuring the services of a qualified professional or team of qualified professions. The qualified professional(s) will prepare an IIP authenticated by the lead referred to as the Professional of Record. The IIP is provided to the dam owner, who submits the completed IIP to a dam safety officer for acceptance. The regulatory authority's preference is for communication to be with the dam owner. IIPs submitted to a dam safety officer undergo a regulatory review, based on the report requirements listed in Section 6 of this document. If satisfied, the dam safety officer will provide written

acceptance. BC has a professional reliance model, meaning the regulatory authority's review is largely regulatory and should not be considered a professional technical review. The expectations are that the submitting Professional of Record will follow Engineers and Geoscientists BC's (EGBC) "Guide to the Standard for Documented Checks of Engineering and Geoscience Work" (2021) and "Guide to the Standard for Documented Independent Review of High-Risk Professional Activities or Work" (2023).

The regulatory review process will be expediated by providing a complete and clear IIP, with risks and precautions described. For detailed instructions on methodology and how to perform an invasive investigation, the dam owner and qualified professionals should refer to comprehensive "how to" guidance documents produced by the U.S. Army Corps of Engineers (USACE), Federal Energy Regulatory Commission (FERC), the Federal Emergency Management Agency (FEMA), and the U.S. Bureau of Reclamation (USBR) and other industry recognized publications.

A dam owner is advised that an invasive investigation program has inherent uncertainty due to the variable nature of soils and bedrock. EGBC's guideline "Site Characterization for Dam Foundations" (2016) advises that a budget contingency allowance of 20% to 50% should be established as part of program planning, to respond to, and effectively manage the inherent uncertainty.

Work that is not covered by this guideline includes plans to alter, improve, replace, decommission or remove a dam. These activities require authorization as per Section 12 and Section 17 of the Dam Safety Regulation. Dam owners and qualified professionals should refer to the BC Dam Safety Technical Guidance documents "Plan Submission Guidelines" (V.14a July 2018[1]) and "Dam Decommissioning Guidelines" (V.1 2019) for information. For clarity, the following activities are considered an alteration or improvement to a dam requiring Section 12 authorization:

- Excavation and backfilling to remove large vegetation and roots
- Installing seepage control features, including foundation grouting, cutoff wall installation
- Anchoring or stabilization construction.

[1] V.15 expected to be published in 2024

3.1. Risk of Invasive Investigations Activities

Potential hazards associated with drilling into a dam include hydraulic fracturing, internal erosion, artesian conditions, contamination of filters and drainage features, heave and damaging existing instrumentation. These failure modes may occur immediately or take weeks to months to be visible on the surface. The guiding principle for any activity on a dam is **DO NO HARM**.

The following activities have a high likelihood of causing unintentional damage to a dam structure:

1. Drilling into a dam core of a zoned embankment dam.
2. Drilling in locations with a high potential for hydraulic fracturing, including:
    a. Near steep abutments, or abutments with abrupt changes in slope angle.
    b. Adjacent to rock overhangs.
    c. Adjacent to buried structures.
    d. Adjacent to conduits.
    e. Narrow zones of soil backfill placed between the structure and rock face.
    f. Thin cores that have experienced more settlement than the adjacent shells.
    g. Dams in very narrow valleys.
    h. In areas subject to differential settlement.
3. Drilling through or near a filter zone, drain zone, or drainpipes. These drilling activities may introduce fines that block and damage the seepage control component of the dam, or may create an unfiltered zones where internal erosion processes could initiate.
4. Trenching or test pitting near the toe of the dam, or near known seepage areas, as this changes the weight on the dam toe, and could cause destabilization, slope instability and dam failure.

For these identified activities and locations invasive investigation or installation of instrumentation may occur, but the work must be clearly justified by the Professional of Record. The Professional of Record must also assess if this activity constitutes High-Risk work as per EGBC guidance.

3.2. Case Studies

The following examples are case studies that demonstrate the need for careful planning and ensuring the team has the right qualifications and experience for the work.

Case Study – WAC Bennett Dam

In 1996, a tourist reported a “pothole” on the crest of the WAC Bennett dam. Upon investigation by BC Hydro staff, a construction survey benchmark tube was observed at the base of the cavity. The existence of the buried survey benchmark had not been documented on construction drawings available to the surveillance staff.

To investigate the condition of the dam core, a Becker drill was brought on site. After advancing the pipe with very little resistance to a depth of 32 m, the drillhole began to open up, resulting in a cavity approximately 2.5 m in diameter and 7 m in depth. A second smaller void associated with another survey benchmark was later discovered.

The cause of the sinkholes was found to be a combination of light compaction around the survey benchmark, proximity to the canyon walls, and the migration of fines. The conditions causing the sinkhole may have developed shortly after first impoundment, however the surface expression did not occur until many years after due to soil arching.

The incident required lowering the reservoir by 2 m, followed by specialized compaction grouting to repair the dam. In total, the investigations and repair cost BC Hydro an estimated $40 million, not including lost power potential from lowering the reservoir.

This case highlights the importance of:

1) proper installation of buried instrumentation, and
2) risks associated with invasive investigations.

Case Study – Unstable Ground

A dam reservoir was lowered so that a test pit excavation for a soil sampling program could proceed. The exposed reservoir slopes dried on surface, but the lower soils continued to be saturated. Two weeks after dewatering an excavator tracked across the edge of the reservoir, where it sank and caused an undrained slope failure.

Retrieving the machine took a day of coordination between the site team and required the use of 3 other excavators. Approximate cost of $20,000 of lost time and production.

Although not a dam safety risk, worker safety and environmental concerns could have resulted. This case study provides as an example of why proper planning, and direction to operators is required to avoid costly and unnecessary delays.

4. Regulatory Acceptance Schedule

Work should be scheduled to allow time for design, planning and regulatory acceptance. The Dam Safety Regulation requires the following minimum timeline for acceptance:

- Invasive Investigation – a dam owner must provide written notification to the dam safety officer of the proposed investigation at least 60 days before the date on which the owner expects the invasive investigation to begin. Then at least 30 days prior to the expected work start date, the dam owner must

- prepare a plan, in the form and with the content specified by a dam safety officer, in relation to the invasive investigation, and
- submit the plan to a dam safety officer for acceptance by the dam safety officer.

- Instrumentation Record (IR) – a dam owner must provide the instrumentation record to a Dam Safety Officer for acceptance at least 60 days prior to the expected work start date.

5. Instrumentation

The Dam Safety Regulation requires a dam owner to install instrumentation necessary to adequately monitor their dam and the area surrounding, or adjacent to the dam. The Dam Safety Regulation, also requires that prior to installing, modifying, replacing or removing an instrument for a dam, an owner must submit an instrumentation record[2], describing the proposed changes. All instrumentation changes to a dam must be accepted by a dam safety officer prior to proceeding.

If instrumentation is installed as part of an invasive investigation, the instrumentation record (IR) should be included as part of the IIP. Table 1 summarizes instrumentation changes that should be made as part of an IIP, and changes that do not require an IIP. If there are questions for if an IIP is required, contact a dam safety officer for advice.

For instrumentation changes where an IIP is not required, the dam owner may prepare the IR or engage a qualified professional to prepare the IR. The instrumentation record should contain the following information:

1. Dam description, including failure consequence classification.
2. Proposed instrumentation changes:
    a. Type of equipment or device, and maintenance/calibration plan
    b. Purpose
    c. Data collection and monitoring plan
    d. Data analyses plan
3. Schedule for work
4. Plan Drawing(s) showing:
    a. Dam features (crest, spillway, low level outlet, etc.)
    b. Access
    c. Restricted areas (if any)
    d. Planned instrumentation installation or removal location(s)

[2] Instrumentation changes may also be described in an annual plan outlining proposed changes for the following year, as per the Dam Safety Regulation, Section 19, (2) (b).

The drawing(s) should be legible, at a scale appropriate to the size of the dam and should have labels to assist in understanding.

Table 1: Instrumentation Changes and Authorization Process

Instrumentation Changes that require an IIP	Instrumentation Changes that require an Instrumentation Record
• Piezometers • Standpipes • Thermistors • Inclinometer casing • Shape arrays • Excavation near a dam toe to install a seepage measurement weir (distance from the dam down is less than the height of the dam) • Downhole seismometers or geophones • Downhole load cells or strain gauges • Internal tilt meter • Excavation greater than 0.3 m to install: Survey monuments, GPS Hubs, surface mounted seismometers, data logger pedestals, cables, etc.	• Excavation less than 0.3 m depth to install: survey monuments, GPS Hubs, surface mounted seismometers, data logger pedestals, trenching for surface cables or other buried utilities • Staff gauge • Surface extensometers or crack meters • Tilt meter • Weather station • Installation of flow meters or turbidity sensors in existing pipes or channels downstream of the dam • Excavation to install a seepage measurement weir, where the distance from the dam toe is greater than the height of the dam • Installation of a water level sensor or shape-array in an existing casing • Installation of a seepage weir in an existing channel

6. Considerations for Planning an Invasive Investigation

An invasive investigation should be planned to collect the required information, ensure the data is good quality, and to not cause unnecessary harm to the dam. The plan should be developed in consideration of a review of existing information, dam model, conceptual geological site model, preliminary analysis, instrumentation requirements, and results from non-destructive measurements. The objective of any plan should be to obtain reliable and representative information while minimizing the number of test holes and other invasive activities.

A program should be developed in consideration of EGBC's professional practice guideline "Site Characterization for Dam Foundations in BC" (2016), the Canadian Dam Association's (CDA) Dam Safety Guidelines, as well as other established best practices.

6.1. Review of Existing Information

For an Invasive Investigation the Professional of Record should have a clear understanding of the dam's history, anticipated embankment and foundation conditions, and the geological site model. A thorough review of existing information should be undertaken to identify 1) any information gaps that might prove important to the safe execution of the program, and 2) identify data that should be collected or verified.

At a minimum, if available, the following information should be reviewed in developing an invasive investigation program:

- Original design reports and drawings
- Construction records and photographs
- Dam Safety Review report(s)
- Instrumentation plans, records, and analyses
- Site surveillance and annual inspection reports
- Geological maps and records for the area
- Publicly available LiDAR data

The existing information review should be considered a process of discovery. As information is reviewed, the initial scope of the invasive investigation requested by the dam owner or proposed by the Professional of Record, may need to be adjusted or expanded, so that the program collects the required information, and the overall risk to the dam structure is kept as low as reasonably possible.

In many cases, preliminary engineering analysis of the structure based on the review of existing information is beneficial. Preliminary analysis assists in identifying risk, failures modes and zones of interest where material properties are sensitive to variation so should be calibrated with in-situ testing or laboratory testing. A conceptual model can be created from the existing information review considering the geometry of the dam, assumed material properties, or using material strengths based on non-destructive testing methods.

6.2. Non-Destructive Options

Prior to performing an invasive investigation, non-destructive options should first be considered. Non-destructive testing can provide information on the hydraulic conductivity of a dam or foundation, density of soil in the dam fill or foundation, approximate locations where dam fill and foundation changes occur, approximate locations of soft materials, areas of settlement, and can be used in empirical

calculations to estimate material strengths and other properties. Additionally, **non-destructive testing does not require regulatory acceptance.**

Some examples of non-destructive options are:

- Remote Satellite Sensing, including InSAR and other new emerging technologies
- Ground penetrating radar (GPR)
- Acoustic emission testing
- Infrared thermography
- Microwaves
- Ultrasonic
- Dye tracers
- Resistivity
- Magnetic and gravity surveys
- Electrical and electromagnetic surveys
- Seismic Refraction/Reflection
- Multichannel Analysis of Surface Waves (MASW)
- Downhole seismic surveying in existing instrumentation casing

6.3. Test Holes and Backfilling Methods

The Professional of Record should consider the specific dam, geological setting, and purpose of the investigation in developing a test hole program to collect required data while reducing risk. For the number and location of test holes, the following should be considered and documented as part of the judgement process:

- Dam height and expected depth of influence to confirm competent strata for static, seismic (pseudo-static), and post-seismic stability analyses.
- Spacing between test holes should be selected considering the expected variability in the conceptual geological site model and size of the dam.

Different test hole and backfilling methods carry different risks as summarized in Table 2 and Table 3. In some cases, a combination of methods may be appropriate, or restricted methods may be necessary.

Table 2 – Drilling methods for embankment dams

Preference	Drilling Method	Comments
Preferred	Hollow Stem Auger	Water/bentonite can be directly added to hole to counteract vertical gradients. Water can be used to offset hydrostatic pressure and void “heave”. Raise and lower auger string slowly when fluid in hole.
	Sonic / Vibratory	Water or drilling fluid must not be pressurized. Water can be used to offset hydrostatic pressure and void “heave”. Consider impact of vibration on in-situ testing quality.
	Cable Tool/ Churn	Chop and drive variation not allowed.
Restricted	Solid Stem Auger	Appropriate in some locations. Not appropriate where artesian conditions may occur because of challenges with closing/sealing hole.
	Cone Penetration Testing (CPT)	Appropriate in some locations. Describe how the hole will be backfilled/sealed.
	Dual Rotation/Fluid Rotary	Volume of water used should be minimized. Specifically direct drillers to use minimal water, as in normal conditions drillers will inject large volumes of water for smoother casing advancement. Frequently dip/measure the water level to check the phreatic surface has not been exceeded. Size tools and bit to reduce likelihood of clogging. Fluid discharge from bit should be upward, not downward, to reduce clogging and pressure spikes. Open bit methods are not allowed. Raise and lower tools/heads slowly to reduce pressure spikes. Advance casing ahead of bit to confine fluids. Fluid pressure must be very low and monitored closely. Clear water or air is not permitted. Use pressure relief valve to cap fluid pressure; and all changes must be gradual.
	Becker Penetration Tests	
	Wireline/Rock Coring/Casing Advancers	
Prohibited	Drill Through / Drive Casings	Not allowed in or near embankment dams.
	Air Rotary	

Adapted from: FERC 2016; USACE 2023 and USBR 2014, refer to these documents for additional details.

Table 3 – Backfill methods for test holes

Preference	Backfill Method	Comments
Preferred	Grout-bentonite mix	Installed with tremie-line placed in bottom of the hole. Staged installation may be required. Grout should be designed to reach a strength equal or greater than the soil/bedrock.
	Grout-cement mix	
	Filter or Drain material	For backfill in specific location if the borehole crosses or is suspected to have encountered these materials.
	Concrete	Where concrete cores are collected from a dam. At surface for mounting instrumentation covers.
	Sand	Around standpipe screen only
Restricted	Coated bentonite pellets	Coated chips are a uniform size so less likely to bridge. These may be appropriate in highly permeable layers (i.e. rockfill dams, or alluvial deposits). Measurements during backfill must be made to check and adjust if bridged.
Prohibited	Drill cuttings	Not allowed.
	Bentonite chips/powder	Bentonite chips are not a uniform size, so are more likely to bridge than coated bentonite pellets.
For boreholes through a dam foundation or abutments, backfill procedures must also follow the BC Groundwater Protection Regulation.		

Adapted from: FERC 2016; USACE 2023 and USBR 2014, refer to these documents for additional details.

6.4. Concrete Cores

Concrete dams have their own unique challenges, particularly embedded services such as electrical conduits, communication services, water lines and drains, and existing instrumentation. It is incumbent on the Professional of Record to review all available records and undertake necessary non-destructive investigations prior to planning any invasive activities for collecting concrete cores.

All concrete core holes should be appropriately backfilled with concrete.

7. Invasive Investigation Plan

An IIP must clearly define the program and justify the purpose of the investigation. When submitting a IIP to a dam safety officer, the following must be included:

1. Technical Plan, with attached assurance statement – prepared by the Professional of Record.
2. Interim Dam Safety Risk Management Plan (IDSRMP) – prepared by a qualified professional engineer.

7.1. Technical Plan

The technical plan should clearly define and justify the invasive investigation program and risks.

The recommended table of contents for a complete technical plan can be found in Appendix A.

7.1.1. Drawings

Drawings must be provided as part of the technical plan. The drawings should be legible, at a scale appropriate to the size of the dam and should have labels to assist in understanding. Appendix B provides a list of expectation for drawings.

7.1.2. Potential IIP Changes

Invasive investigations all carry a degree of uncertainty. Based on observations in one test hole, there may be reason to add additional test holes, change locations or excavate deeper. These types of changes carry additional risk if not carefully considered so should be pre-emptively identified, and included as a potential in the technical plan. A dam safety officer **will not** provide acceptance of these types of changes through a phone call.

7.1.3. Qualifications of Team

The technical plan should identify the specific individuals who will be performing the work and their education, training and experience.

Professional of Record should be a professional engineer, who has qualifications and experience in dam design, construction and analysis. Their experience should be commensurate with the complexity of the dam. Ideally, this individual would have minimum of four years of geotechnical experience directly related to dam safety.

The Dam Safety Regulation requires that all drilling, trenching, test pit excavations and other activities involved in an invasive investigation is directly supervised by an engineering professional who has qualifications and experience in dam design, construction, and analysis. The BC Dam Safety Program's expectations on minimum qualifications for on-site supervision are described in Table 4.

A driller must be registered as a Geotechnical/Environmental Driller and hold a Certificate of Qualification, as required by the Groundwater Protection Regulation.

Table 4: Minimum Qualifications for On-site Supervising Professional

Factor	Low Consequence Dams	Significant Consequence Dams	High to Extreme Consequence Dams
Education	n/a	Professional engineer	
Training	n/a	Independent study or formal training in the identification and mitigation of drilling hazards in embankment dams	
Experience	n/a	Minimum of two years of general drilling experience	Minimum of four years of drilling experience, and minimum of four years geotechnical experience directly related to dam safety (years of experience may overlap).

7.1.4. Professional Review and High-Risk Work Assessment

Invasive activities in and near dams may adversely impact the dam structure and in rare cases, can cause an unexpected incident potentially leading to dam failure.

An invasive investigation could potentially be considered high-risk work for dams with a consequence classification of "High to Extreme". In high-risk circumstances, professional registrants must meet the requirements for independent review. Professional registrants should substantiate their decision whether and how to carry out independent review, with a documented risk assessment that follows the requirements of the "Guide to Standard on Independent Review of High-Risk Professional Activities and Work" (EGBC, 2023). The conclusion on the Professional of Record's review must be documented in the assurance statement.

7.1.5. Assurance Statement

An authenticated assurance statement must be attached to the technical plan. The required assurance statement form is provided in Appendix B of this guideline.

7.2. Interim Dam Safety Risk Management Plan

An Interim Dam Safety Risk Management Plan (IDSRMP) is required to be submitted as part of the IIP. The IDSRMP is intended to identify and address all potential hazards associated with the invasive investigation program and manage or mitigate the risks. An IDSRMP will establish enhanced surveillance requirements and procedures for completing the proposed work.

The IDSRMP should include the following elements:

- Reservoir water level required prior to starting work.
- Enhanced visual surveillance during the work and who is responsible.
- Instruments that will be monitored during the work for unexpected response. Include defined set threshold values and action plans for unexpected response and changes.
- If drilling and drilling fluid will be used, describe how the drilling fluid will be circulated and tracked to identify losses.
- Identification of plausible hazards or failure modes that could occur as a result of the work.
- Planned responses to hazardous conditions or changes observed during or following the work. The planned responses should include phone numbers and people who should be notified.
- Emergency supplies that will be available on site during the investigation (for example, fill material, filter material, grout, backhoe, phone or radio, etc.).
- After the investigation, describe requirements for enhanced surveillance activities, timeframe and who will be responsible.

Prior to starting an IIP, the dam owner must confirm the Dam Emergency Plan (DEP) and phone numbers are current.

The IDSRMP must be authenticated by a qualified professional. This may be the Professional of Record who prepared by the technical plan, or a separate qualified professional on behalf of the dam owner.

8. Field Work for an Invasive Investigation Program

The following must be on site during the work:

- A physical copy of the IIP including 1) technical plan and 2) IDSRMP,
- A physical copy of the dam safety officer’s acceptance letter of the IIP,
- A physical copy of the DEP, and
- Any equipment or supplies required in the IDSRMP.

A dam safety officer may come to the work site during the work, to confirm the work is occurring as planned.

9. Invasive Investigation Reporting

The purpose of an invasive investigation is generally to collect data to create a model for engineering analysis of a dam and foundation. Dams have a long lifespan, so the data from an invasive investigation should be documented in a format that can be referenced and understood by a different qualified professional.

The invasive investigation report should be prepared and authenticated by the Professional of Record following requirements by EGBC. As dam work carries an inherent risk, the BC Dam Safety Program requests that report authentication pages identify:

- Professional of Record, as well as other contributing author(s), and reviewer(s).
- Reports should identify the revision number and summary of changes.
- Dam safety work is often multidisciplinary, so where input is required from one or more professional specialists, each specialist must authenticate the document and qualify the extent of their responsibility. *For example, an invasive investigation report may be authenticated by a geotechnical engineer, a hydrogeologist, geophysics, and a Professional of Record who coordinated the other professionals.*

9.1. Reporting Schedule

The invasive investigation report should be prepared and submitted to the dam safety officer for acceptance within six months of completion of the field work. Any expected delays for submission should be communicated to the dam safety officer.

9.2. Invasive Investigation Completion Report

Table 5 summarizes the expected information to be included in an invasive investigation report.

Table 5: Information for an Invasive Investigation Completion Report

Information	Comments
Dam Description	Describe dam and identify the failure consequence classification
Objectives and justification	Describe the justification and objective for the invasive investigation. Include a statement on if the planned objective was met.

Information	Comments
Summary of Invasive Investigation Program	Provide details on when the work occurred, who supervised the work, equipment used, backfill details, and survey method. Identify if there were limitations or restrictions relevant to data collection.
In-situ Testing Performed	Provide factual details so the data may be used by a different qualified professional to perform an analysis. Include information on testing equipment model, dimensions, energy, loading conditions, etc.
Laboratory Testing	Describe testing performed, sample location and results. Provide references to method as appropriate.
Stratigraphy / Lithology / Concrete	Industry accepted engineering methods for the interpretation and description of soil, rock and concrete should be used. The classification method or system should be stated, and if a modified method is used additional explanation provided. Group soil or bedrock into units of similar characteristics. Describe measured parameters or observations for each unit. As required by EGBC a qualified professional should clearly distinguish between facts, their interpretation, their opinion and how conclusions were reached.
Reservoir water Level and Phreatic Surface	Water level/elevation in reservoir during the work. Water level/elevation measured in the test holes during and/or after the work.
Instrumentation	Describe instrumentation installed, and calibration details during installation.
Recommendations	Recommendations to the dam owner as a result of the findings from the invasive investigation program. If the invasive investigation identifies previously unknown conditions that could be a potential safety hazard or hazardous condition, this should be clearly stated, and a recommendation made to change operation as required for safety. *For example, if drilling identified karst voids in the dam foundation, the dam reservoir level may need to be lowered.*
Drawings	• Refer to planning drawing requirements in Section 6.1.5. Update drawings to show actual test hole locations. • Section(s) and/or profile(s) showing a stick-log of the concrete/soil/bedrock encountered, compared to other known or assumed conditions.
Attachments:	• Test hole logs and classification reference sheet. • Photographs of the equipment, recovered sampled soils, bedrock, and concrete, as well as other features of interest (organic material, debris, etc.)

Information	Comments
	• Instrumentation field calibration records and manufacture calibration records (as applicable) • Lab testing results

10. Changes to Operation Maintenance and Surveillance (OMS) Manual

After instrumentation is installed, or an invasive investigation is completed the Operation, Maintenance and Surveillance (OMS) Manual for the dam will likely need to be revised and updated. Updates may include:

- Information in the dam description or history that the invasive investigation was performed.
- If instrumentation was installed the following must be added:
    - Type of equipment or device, and maintenance/calibration plan
    - Purpose
    - Data collection and monitoring program
    - Data analyses plan
    - Summary of typical reading ranges, and warning/alarm thresholds
- Other changes as recommended by the Professional of Record who supervised and reported on the invasive investigation.

The dam owner must submit a revised OMS Manual to the dam safety officer for acceptance, within 12 months of completion of the instrumentation installation or invasive investigation.

11. References

BC Dam Safety Regulation, 40/2016, February 29, 2016.

BC Hydro, Engineering Standard “Justification and Risk Mitigation for Drilling or Excavation in Embankment Dams and Their Foundations”. March 2018.

BC Hydro “Expert Engineering Panel Report WAC Bennett Dam Report Volume 1”, Kaare Hoeg, Robin Fell, Rodney Bridle, August 2012.

Canadian Dam Association (CDA) “Dam Safety Guidelines 2007”. 2013 Edition.

EGBC (formerly APEGBC) Professional Practice Guideline. “Site Characterization for Dam Foundations Version 1.2”, 2016.

EGBC, Professional Practice Guideline. “Guide to the Standard for Documented Checks of Engineering and Geoscience Work, Version 3.0” 2023.

EGBC, Professional Practice Guideline “Guide to the Standard for Documented Independent Review of High-Risk Professional Activities or Work, Version 2.0”, 2023.

Federal Energy Regulatory Commission, Division of Dam Safety and Inspections. “Guidelines for Drilling in and Near Embankment Dams and Their Foundations”, Version 3.1 – Approved for Public Release June 2016.

U.S. Army Corps of Engineers, Publication No. ER 1110-1-1807, “Drilling and Invasive Activities at Dams and Levees”, June 1, 2023.

U.S. Bureau of Reclamation, “Guidelines for Drilling and Sampling in Embankment Dams”, April 2014.

12. Appendix A – IIP Components

An example Table of Contents for an IIP technical plan should include, but is not limited, to the following information:

1. Objective and justification
2. Dam description, including failure consequence classification
3. Existing information review and data gap identification
4. Dam and foundation conceptual model
5. Failure modes relevant to the invasive investigation
6. Invasive investigation method including equipment type, backfilling, surveying and proposed in-situ and laboratory testing
7. For each test hole:
    a. Objective
    b. Equipment access
    c. Potential hazards and mitigation
    d. Instrumentation installation (if applicable)
8. Instrumentation record (if applicable)
    e. Type of equipment or device, and maintenance/calibration plan
    f. Purpose
    a. Data collection and monitoring plan
    b. Data analyses plan
9. Other considerations, such as public safety, environmental considerations, and archaeology.
10. Invasive investigation schedule
11. Invasive investigation team qualifications
    a. Professional of Record
    b. On-site supervising professional
12. Attachments
    a. Statement of High-Risk Work Assessment
    b. Statement of qualifications
    c. Assurance Statement
    d. Drawings

13. Appendix B – Drawing Requirements

Plan and cross-section(s) showing:

- Dam features (crest, spillway, low level outlet, etc.)
- Embankment zone(s) and material(s) including core, filters, drains, buried drainage pipes and foundation/abutment contacts.
- Anticipated foundation soil/rock types and contacts.
- Anticipated phreatic surface level.
- All ancillary components (i.e. outlet works).
- Buried utilities and through penetrating structures.
- Existing instrumentation.
- Existing or historical distress features (slumps, fractures, boils, etc.) and seepage zones.
- Planned test hole locations, in-situ testing, and sampling areas.
- Planned instrumentation installation, including depth and planned backfill details (screen, seal, stickup, surface seal, cover, etc.)

Plan drawings of the dam and reservoir showing:

- Access
- Inspection and surveillance locations
- Restricted areas (if any)
- Areas relevant to the Dam Emergency Plan (DEP) or Interim Dam Safety Risk Management Plan (IDSRMP)

14. Appendix C - Assurance Statement

This invasive investigation technical plan was prepared by, and reviewed by experienced professionals and follows Engineers and Geoscientists BC requirements, BC Dam Safety Guideline on Invasive Investigation Plans and Instrumentation Records, and other good established practices. The proposed work is justified and was developed to minimize the likelihood of damage to the structure(s) identified below.

1. Dam(s): (list all dams included in IIP)

Dam Owner:	
Dam Name(s):	
Dam Number(s):	
Dam Consequence Classification:	

2. <u>High-Risk Work</u>

Is this work High-Risk (yes or no):	
If yes, who completed the Independent Review:	
If yes, firm that Completed Independent Review:	

I have signed, sealed, and dated the attached Invasive Investigation Technical Plan in accordance with Engineers and Geoscientists BC requirements and the BC Guidelines on Invasive Investigation Plans & Instrumentation Records, and have included a statement of qualifications as an individual or multidiscipline team lead.

<table>
<tr><td colspan="2">Name and title of Professional of Record:</td><td rowspan="3">(Affix professional seal, signature, and date here; Permit to Practice number to be included if applicable)</td></tr>
<tr><td colspan="2">Company name and address:</td></tr>
<tr><td>Telephone:</td><td>Email:</td></tr>
</table>