TAILINGS POND DESIGN, MAINTENANCE AND INSPECTIONS

2020 IAAP Convention

Springfield, Illionis

Presented by Patrick Harrison, P.E., Senior Consultant

March 5th, 2020

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PRESENTATION OBJECTIVES

SURFACE TAILING IMPOUNDMENTS

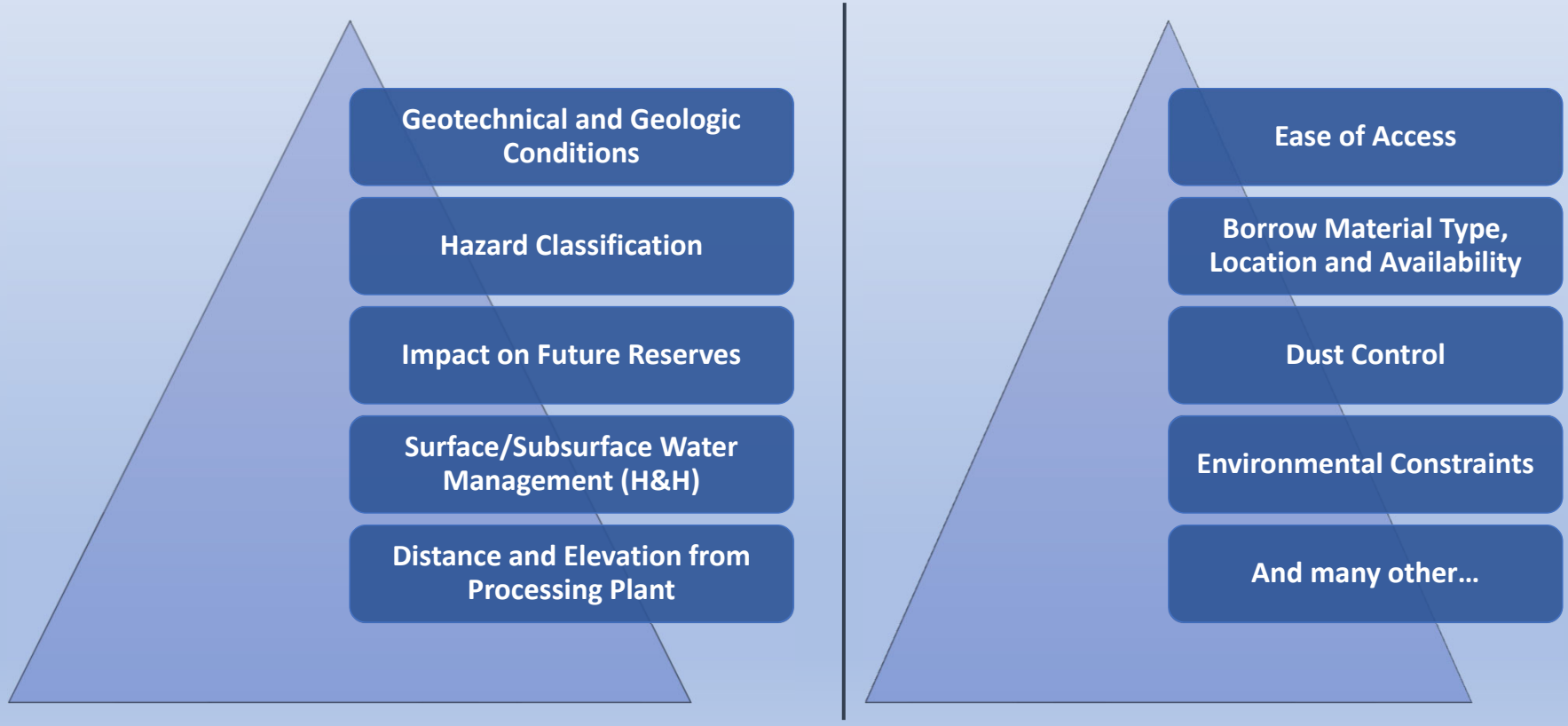
- Overview of Engineering Design
- Project Design Approach
- Construction Oversight
- Inspection and Maintenance

Why is Engineering Design Important?

Comply with Federal, State and Local Regulations and Permit Requirements

Reduce Risk - Major Failures have led to an Industry-Wide Review of Design and Management Practices

WHY ARE SOME ENGINEERING DESIGN CONSIDERATIONS?



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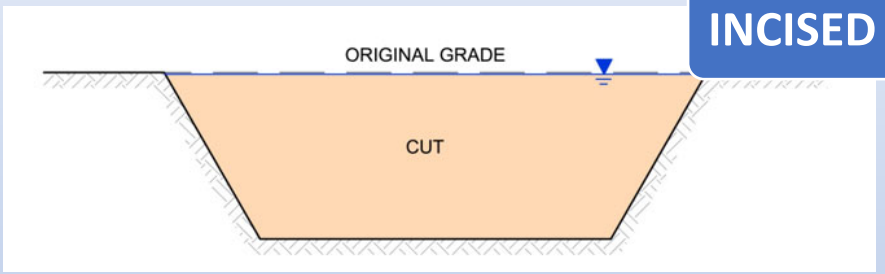
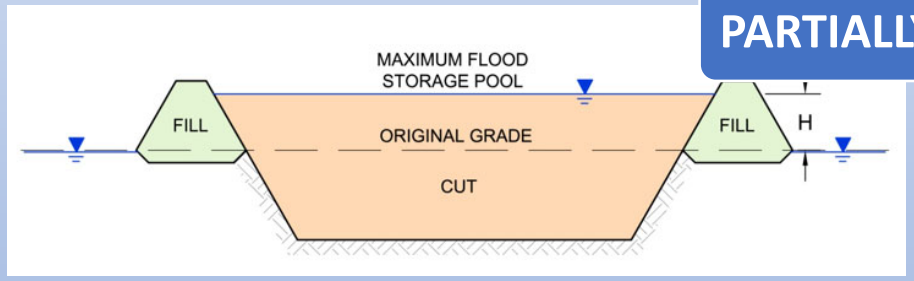
TYPES OF IMPOUNDMENTS

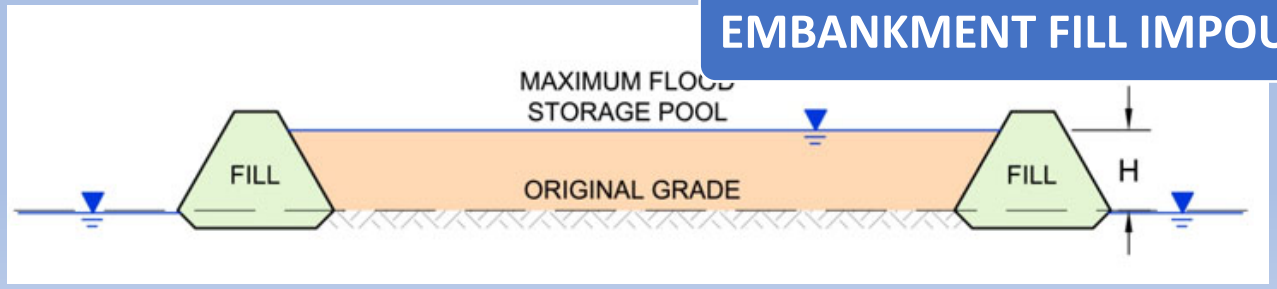
INCISED IMPOUNDMENT



PARTIALLY INCISED IMPOUNDMENT



EMBANKMENT FILL IMPOUNDMENT



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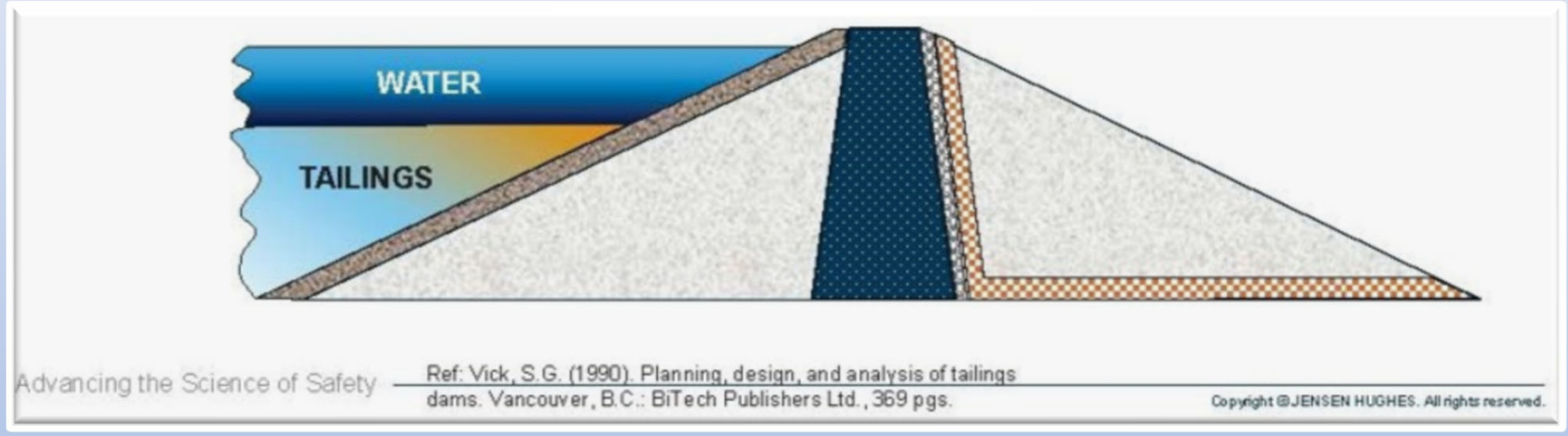
GENERAL DESIGN TYPES

MAIN DESIGN APPROACHES

- Embankment
- Upstream
- Centerline
- Downstream

Reference: Klohn, E. “Taconite Tailings Disposal Practices”, Geotechnical Practices in Mine Waste Disposal, A.S.C.E., New York, NY, 1979, pp 202-241
Reference: Vick S.G.,1990

GENERAL DESIGN TYPES:
EMBANKMENT



Advancing the Science of Safety

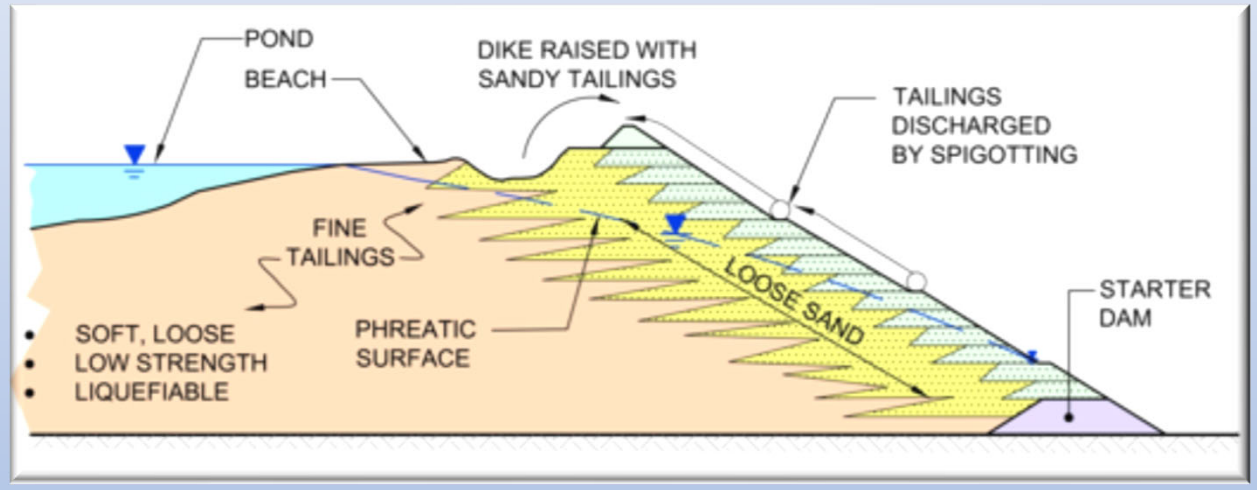
Ref: Vick, S.G. (1990). Planning, design, and analysis of tailings dams. Vancouver, B.C.: BiTech Publishers Ltd., 369 pgs.

- Constructed to full height prior to deposition
- Good permanent tailings and water storage
- Good seismic resistance

- Requires compacted natural borrow materials
- Relatively high cost

GENERAL DESIGN TYPES:

UPSTREAM



- Constructed progressively using tailings
- Most common worldwide
- Lowest cost compared to other methods

- Not suitable for significant water storage
- Poor seismic resistance
- Raising rate restrictions of 15-30 feet per year may apply

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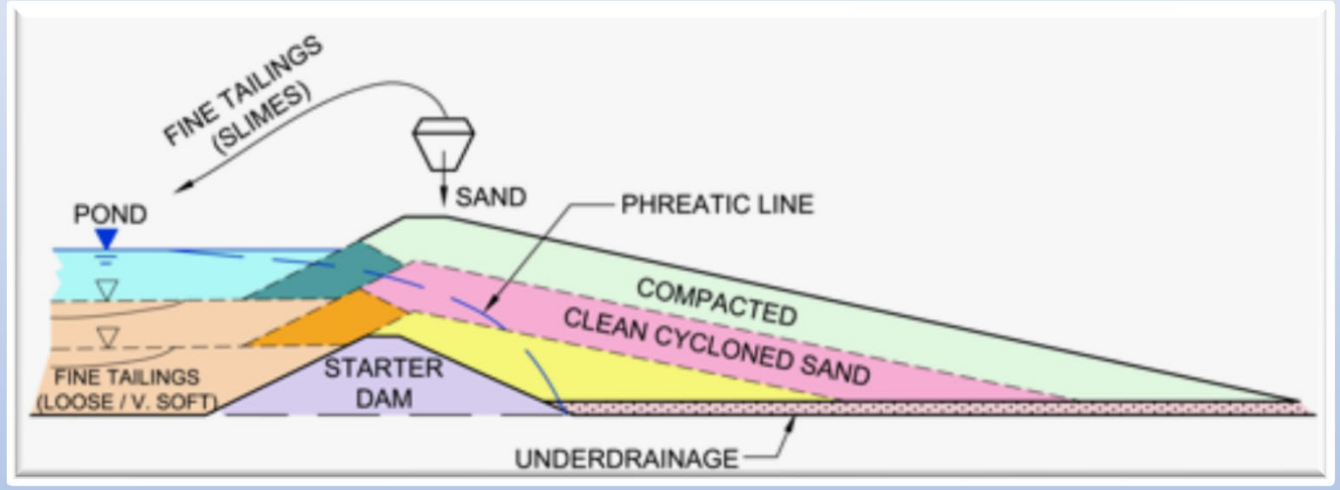
GENERAL DESIGN TYPE:

CENTERLINE



- Constructed progressively using tailings or natural borrow materials
- Good temporary water storage ability
- Moderate cost
- Acceptable seismic resistance
- Raising rate restrictions may apply

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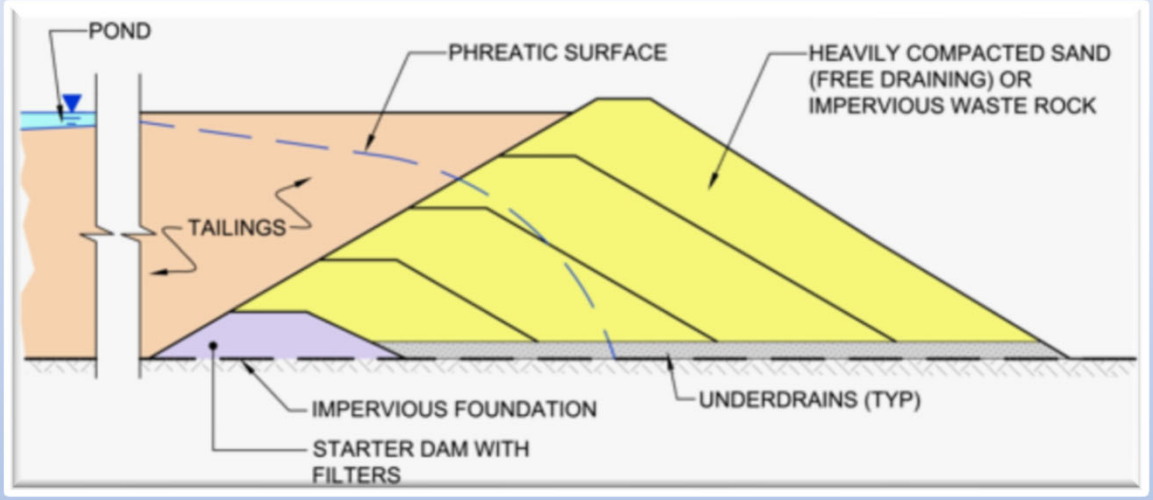
GENERAL DESIGN TYPES:

DOWNSTREAM



- **Constructed progressively using tailings or natural borrow materials**
- **Good permanent water storage suitability**
- **Good seismic resistance**

Relatively high cost (compared to centerline and upstream construction methods)

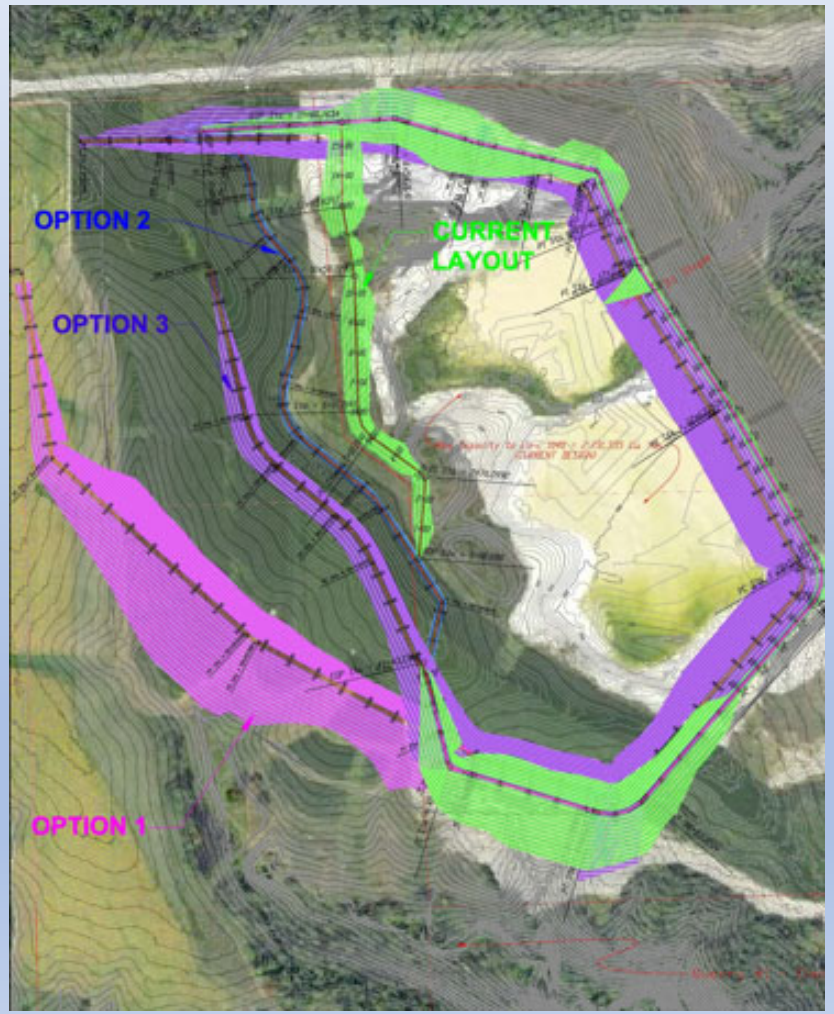
DO SURFACE TAILINGS IMPOUNDMENTS HAVE A HIGHER RISK OF FAILURE?

Failure rate over the past 100 years is estimated to be 1.5%[1]

More than 100 times higher than conventional water storage dams at 0.01%[2]

WHY ARE TAILINGS IMPOUNDMENTS DIFFERENT FROM OTHER DAMS?

- **Often raised repeatedly over their lifecycles**
- **Stores a mixture of minerals and water**
- **When full, they generally remain in place (risk remains for many years)**



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WHAT ARE THE MOST COMMON CAUSES OF IMPOUNDMENTS FAILURES?

OVERTOPPING 01

PIPING THRU EMBANKMENT 02

PIPING THRU FOUNDATION 03

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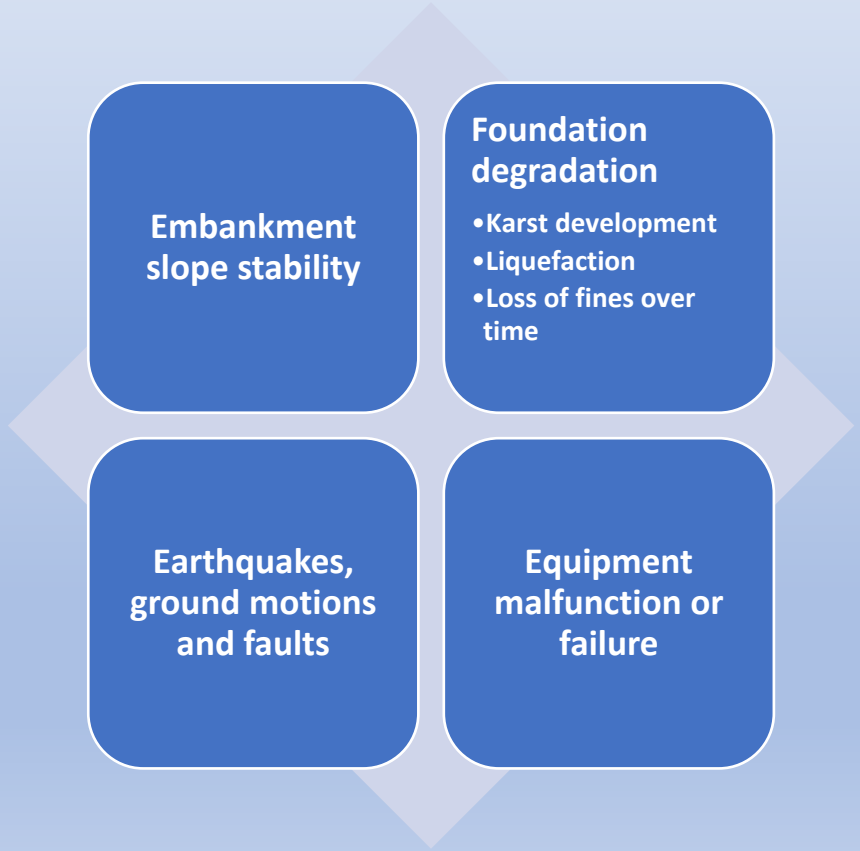
OTHER COMMON CAUSES OF IMPOUNDMENTS FAILURES



WHAT DO COMMON FAILURE CAUSES LOOK LIKE?

OVERTOPPING (most common)

- Uncontrolled flow of water over, around and adjacent
- Erosive wave action

WHAT DO COMMON FAILURE CAUSES LOOK LIKE?

PIPING THROUGH EMBANKMENT

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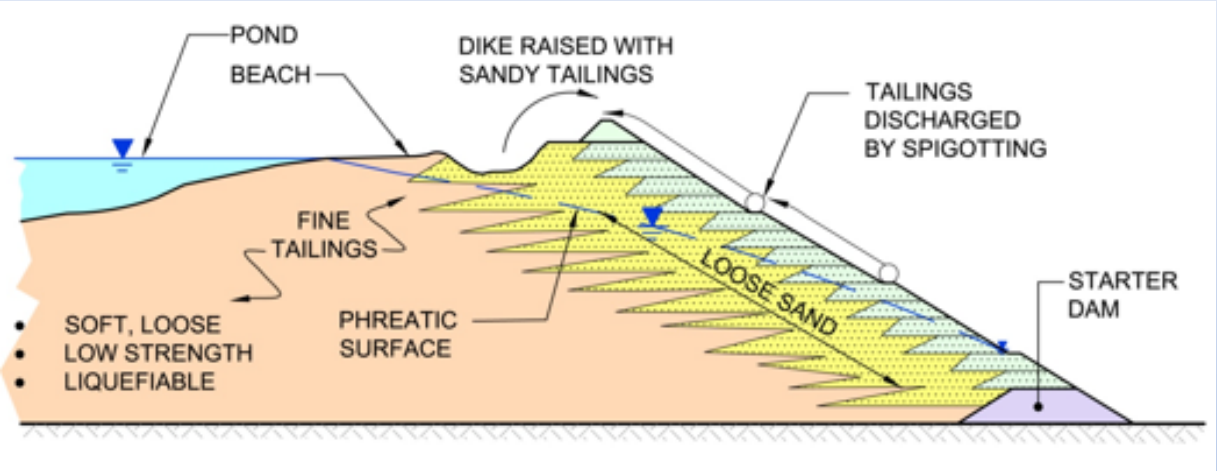
GEOTECHNICAL ISSUES WITH EMBANKMENTS



UPSTREAM CONSTRUCTION METHOD

- Low shear strength tailings – soft, loose
- No internal drainage, high water pressures
- Poor compaction of fill materials
- Steep side slopes
- Weak foundation
- Liquefiable soils under seismic loads

GEOTECHNICAL ISSUES WITH EMBANKMENTS

BEFORE	AFTER

Feijão Dam Failure January 24th, 2019

Brazil Vale S.A.'s Córrego do Feijão Iron Ore Mine

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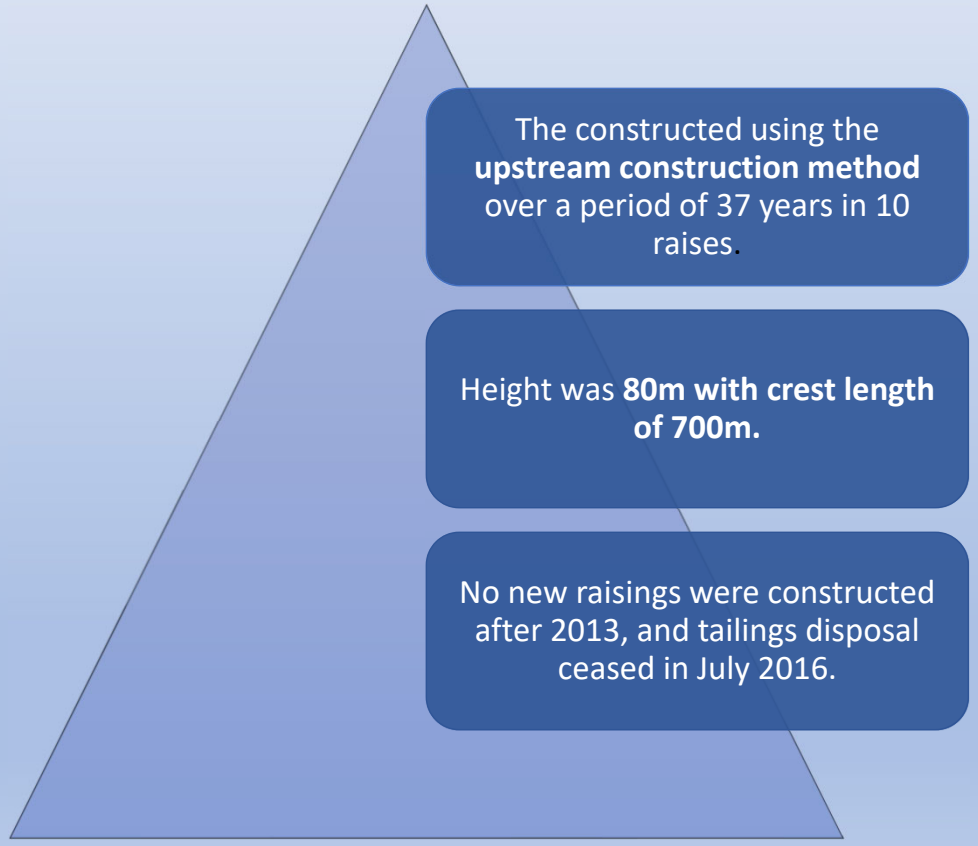
GEOTECHNICAL ISSUES

FEIJAO DAM BASELINE CONDITIONS



Reference: "Report of the Expert Panel on the Technical Causes of the Failure of Feijao Dam I", December 12, 2019

FEIJAO DAM FAILURE

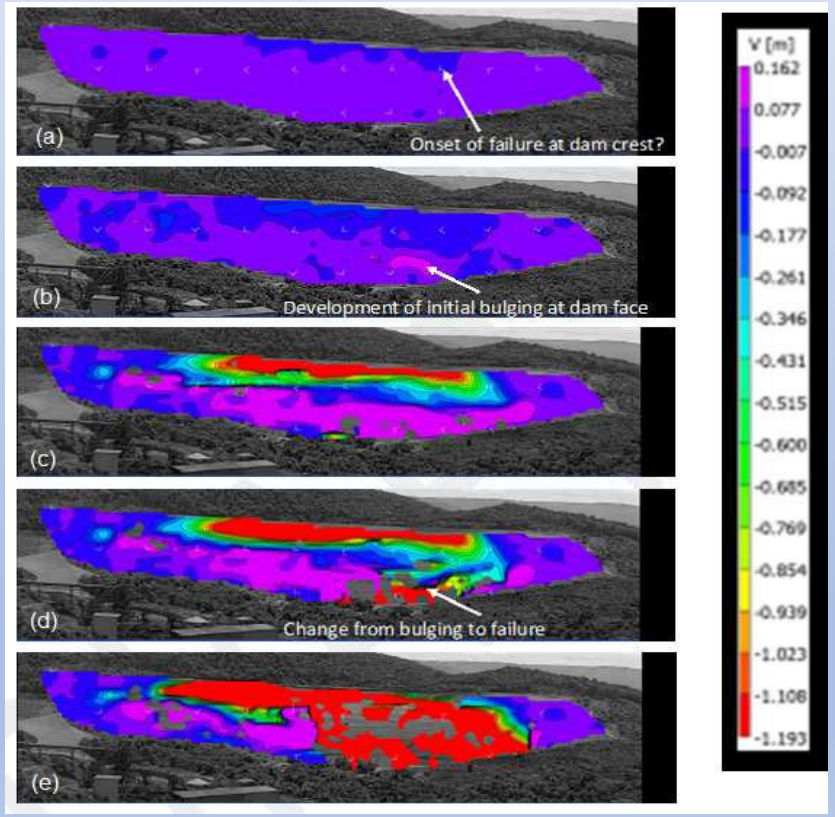


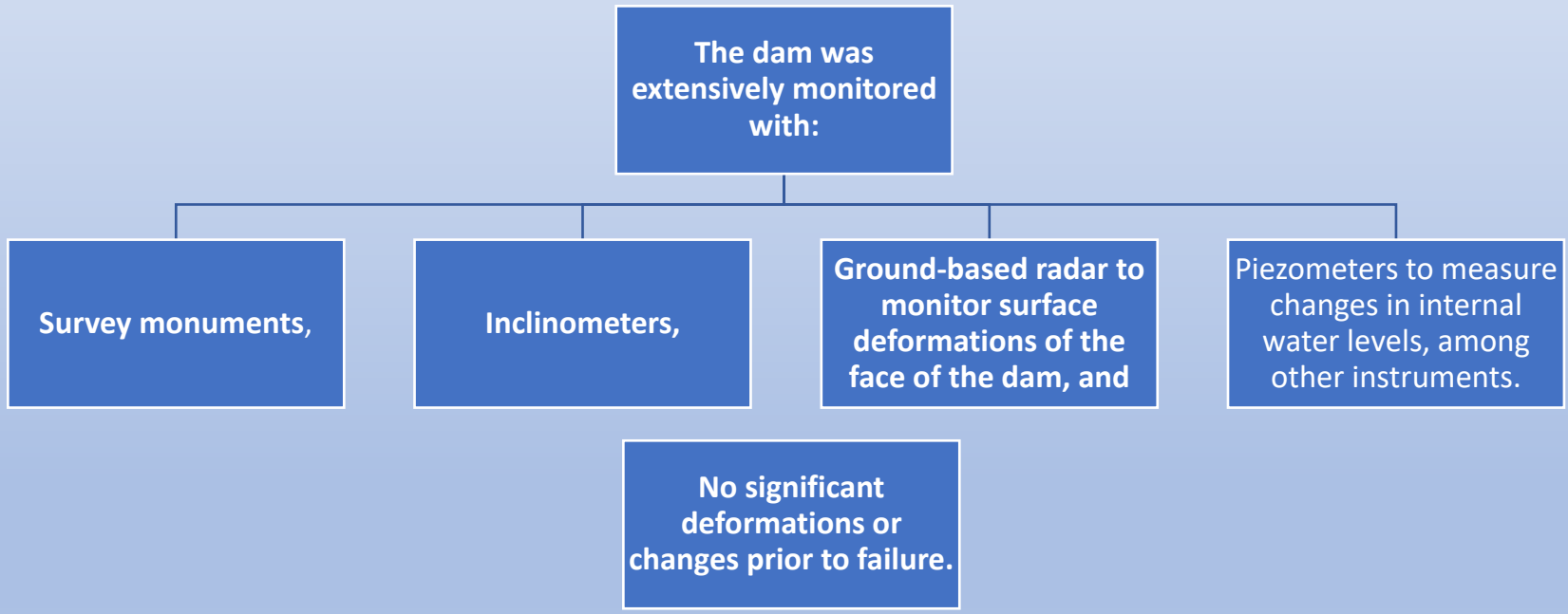
Figure 18: Failure of Dam I[1]

- Observed Initiation (OI) at the Center of the Crest;
- 0.2 s After OI, Initial Bulging of the Face;
- 1.4 s After OI, Showing Escalation;
- 2.4 s After OI, Widening Collapse of the Crest and Increased Bulging of the Face;
- 2.6 s and 3.6 s After OI when the Crest and Bulging Join in Failure

[1] Reference: "Report of the Expert Panel on the Technical Causes of the Failure of Feijao Dam I", December 12, 2019

GEOTECHNICAL ISSUES

FEIJAO DAM FAILURE MONITORING SYSTEMS



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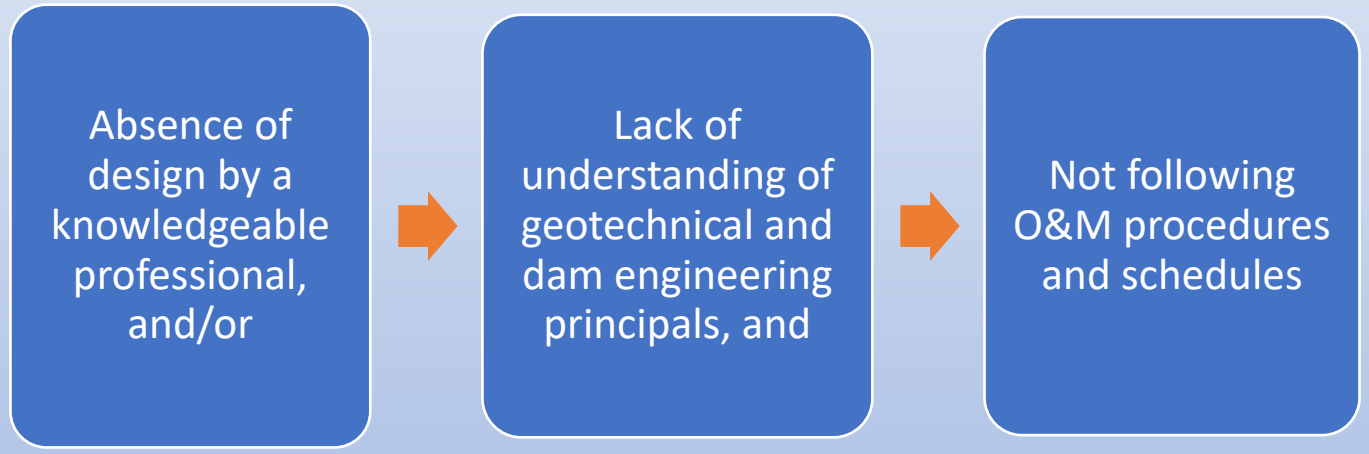
PRIMARY FACTORS AFFECTING FAILURES



DESIGN APPROACH OVERVIEW

DAM SIZE and HAZARD CLASSIFICATION (varies by state)

HAZARD CLASSIFICATION	HAZARD POTENTIAL
HIGH	Probable loss of life Major economic losses
SIGNIFICANT	Possible loss of life Major economic losses
LOW	Loss of life not expected Minimal property damage

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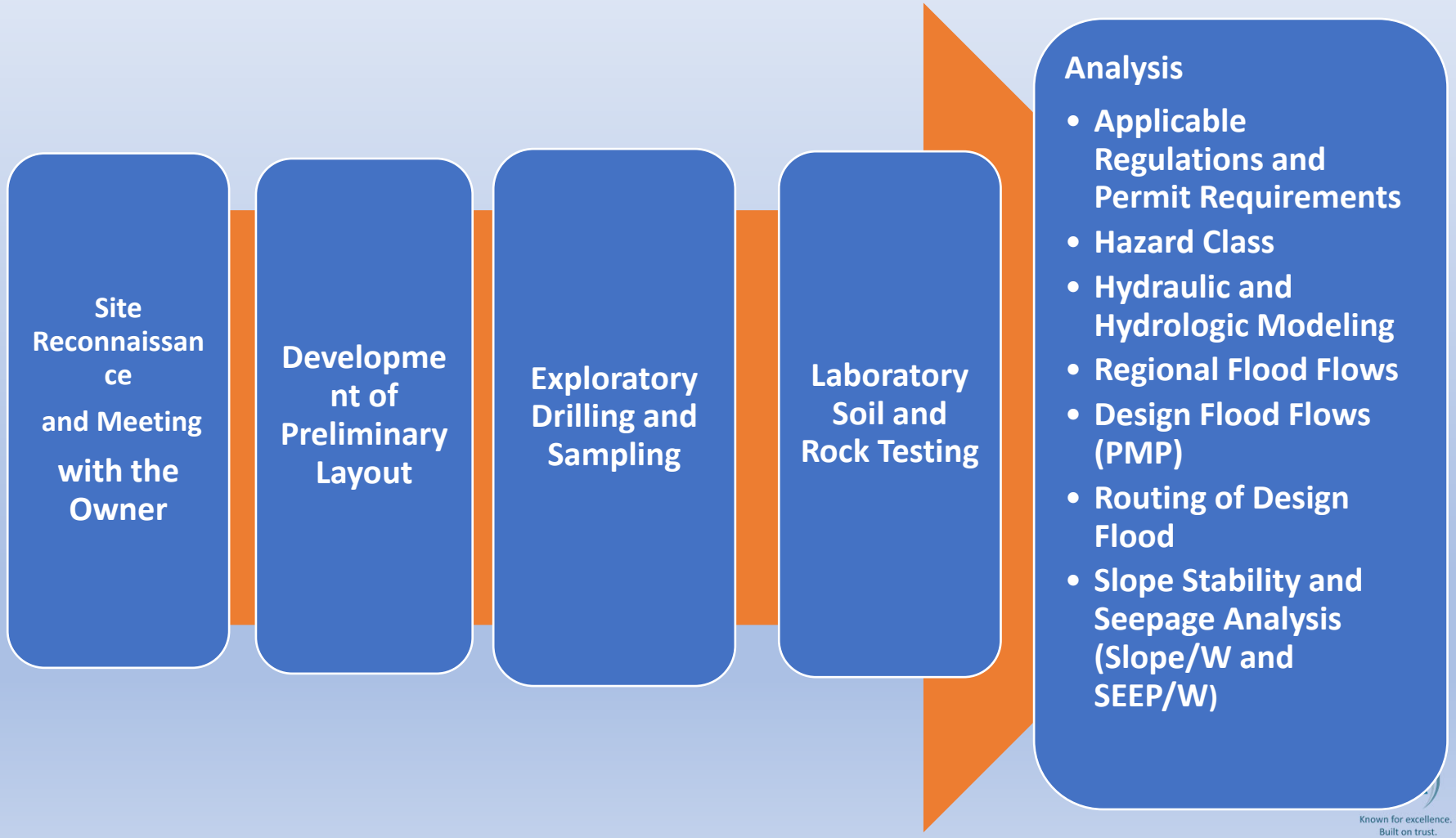
DESIGN OVERVIEW

The following tasks are for a site located in the Midwest:



DESIGN OVERVIEW

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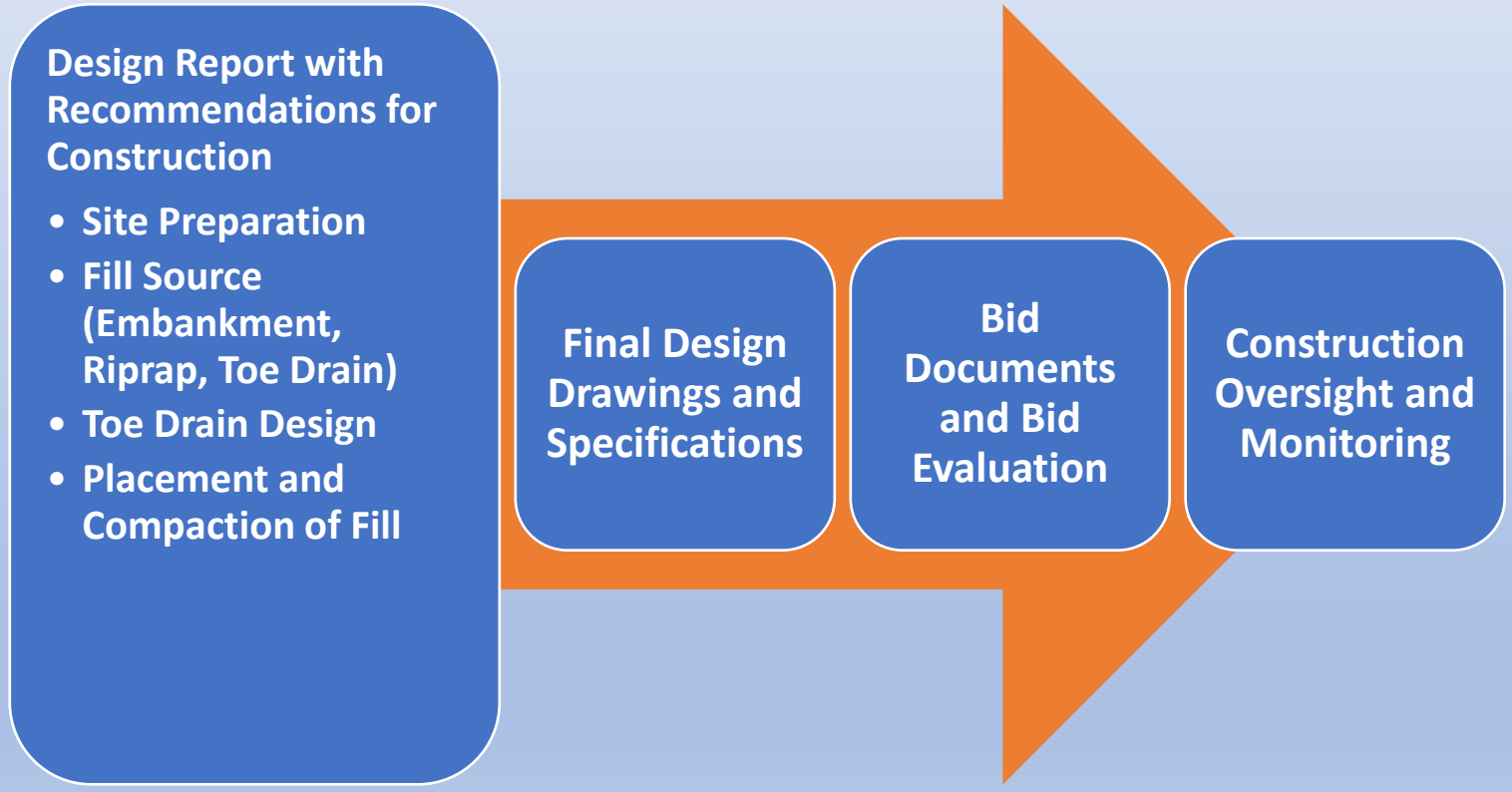
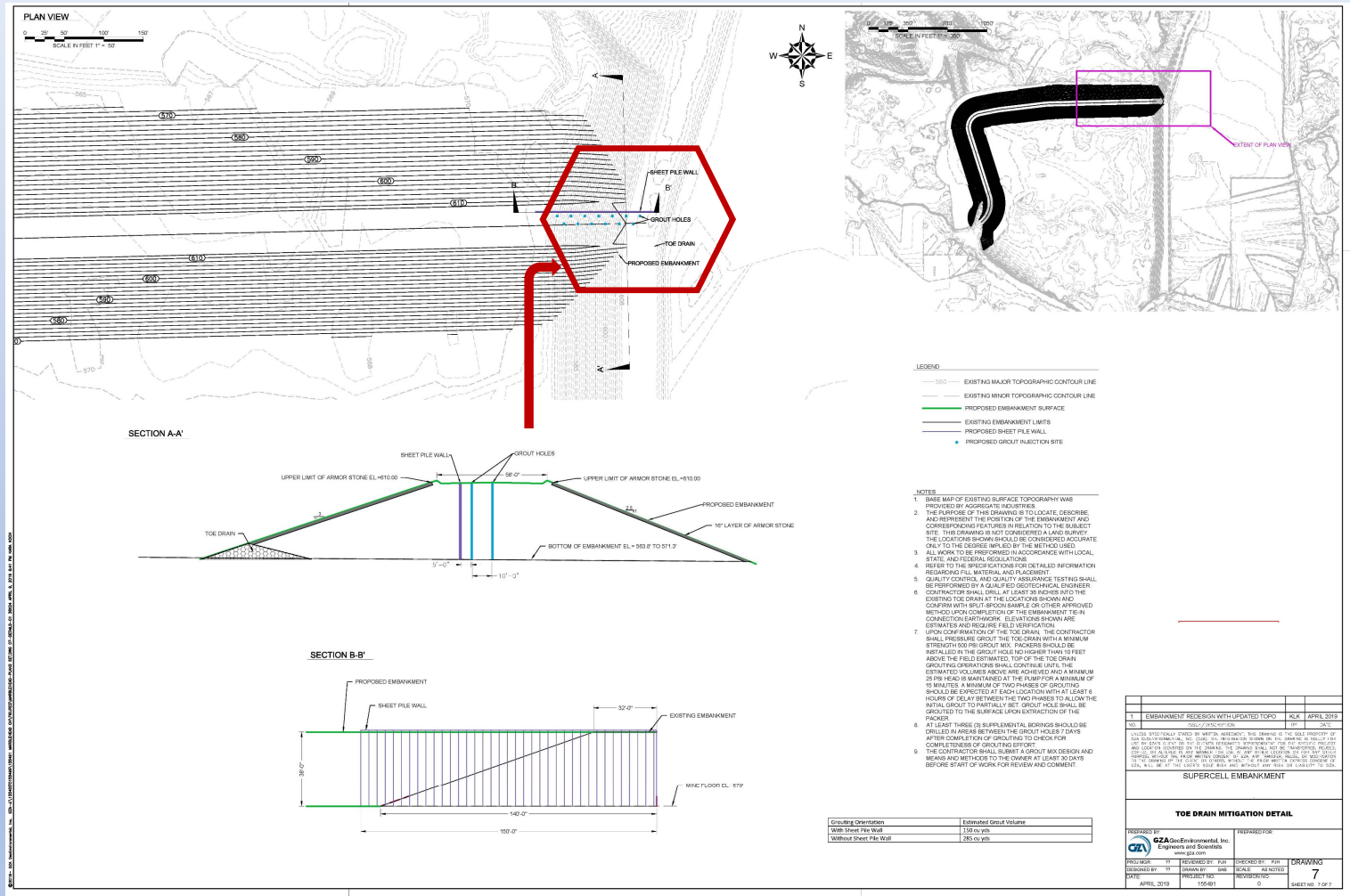


EXISTING TOE DRAIN MITIGATION



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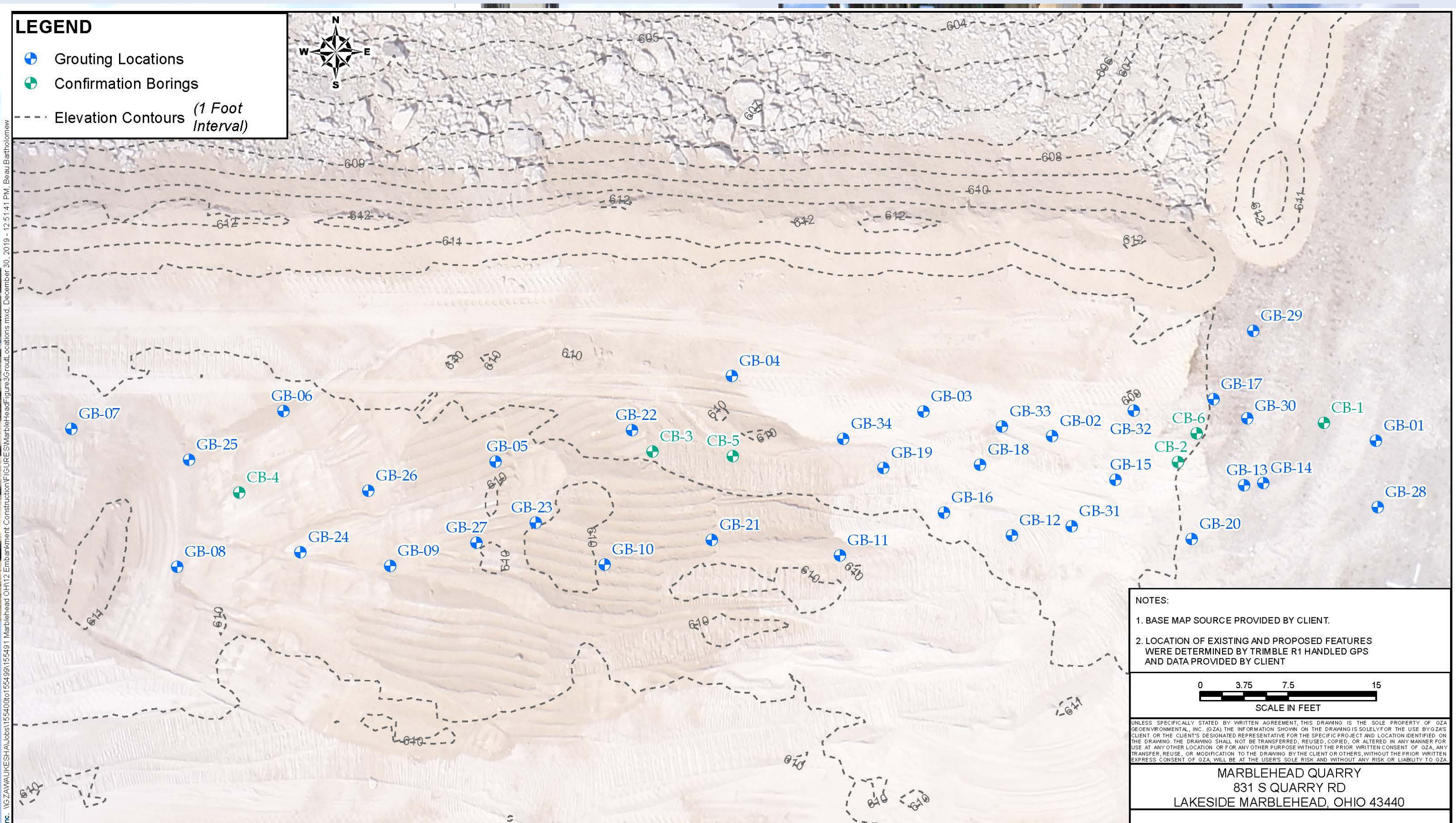
TOE DRAIN GROUTING



Boring ID	GB-01	GB-02	GB-03	GB-04	GB-05	GB-06	GB-07	GB-08	GB-09	GB-10	GB-11	GB-12	GB-13	GB-14	GB-15	GB-16	GB-17
Grout Volume (cuft)	120	48	45	45	32	27	62	22	14	40	97	58	65	122	38	38	81

Boring ID	GB-18	GB-19	GB-20	GB-21	GB-22	GB-23	GB-24	GB-25	GB-26	GB-27	GB-28	GB-29	GB-30	GB-31	GB-32	GB-33	GB-34
Grout Volume (cuft)	108	121.5	41	13.5	13.5	30	30	54	30	81	162	30	27	288	54	30	54

NOTES:

1. BASE MAP SOURCE PROVIDED BY CLIENT.
2. LOCATION OF EXISTING AND PROPOSED FEATURES WERE DETERMINED BY TRIMBLE R1 HANDLED GPS AND DATA PROVIDED BY CLIENT

0 3.75 7.5 15
SCALE IN FEET

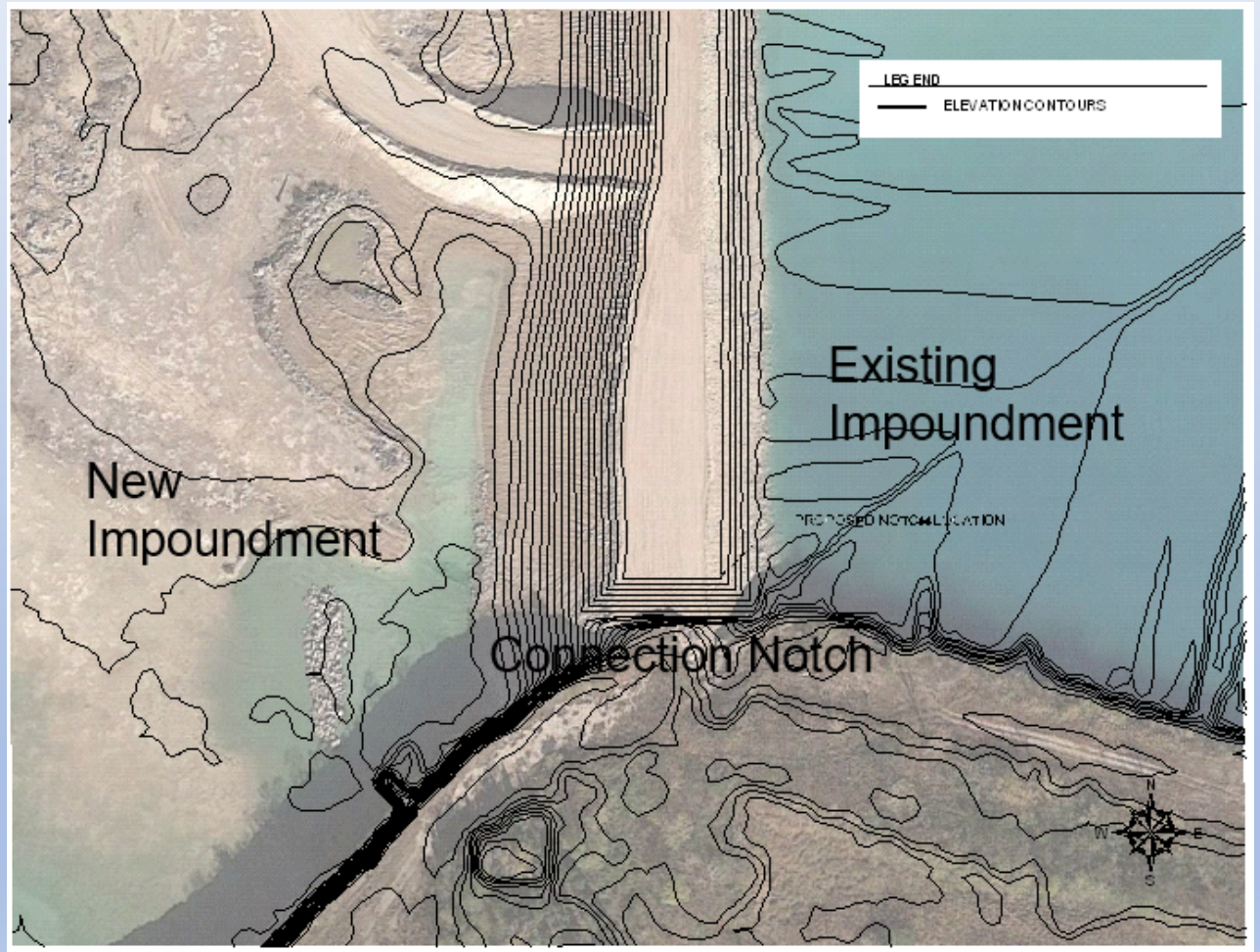
MARBLEHEAD QUARRY
831 S QUARRY RD
LAKESIDE MARBLEHEAD, OHIO 43440

APPROXIMATE GROUTING LOCATIONS

PREPARED BY: GZA GeoEnvironmental, Inc. Engineers and Scientists www.gza.com
PREPARED FOR: LafargeHolcim

PROJ MGR: JDG	REVIEWED BY: MJK	CHECKED BY: PJH	FIG 3
DESIGNED BY: MAD	DRAWN BY: MAD	SCALE: 1 in = 8 ft	
DATE: 12/30/2019	PROJECT NO: 20.0155491.12	REVISION NO: 2	SHEET NO: 2 OF 5

EXISTING EMBANKMENT NOTCH DETAIL



not to scale

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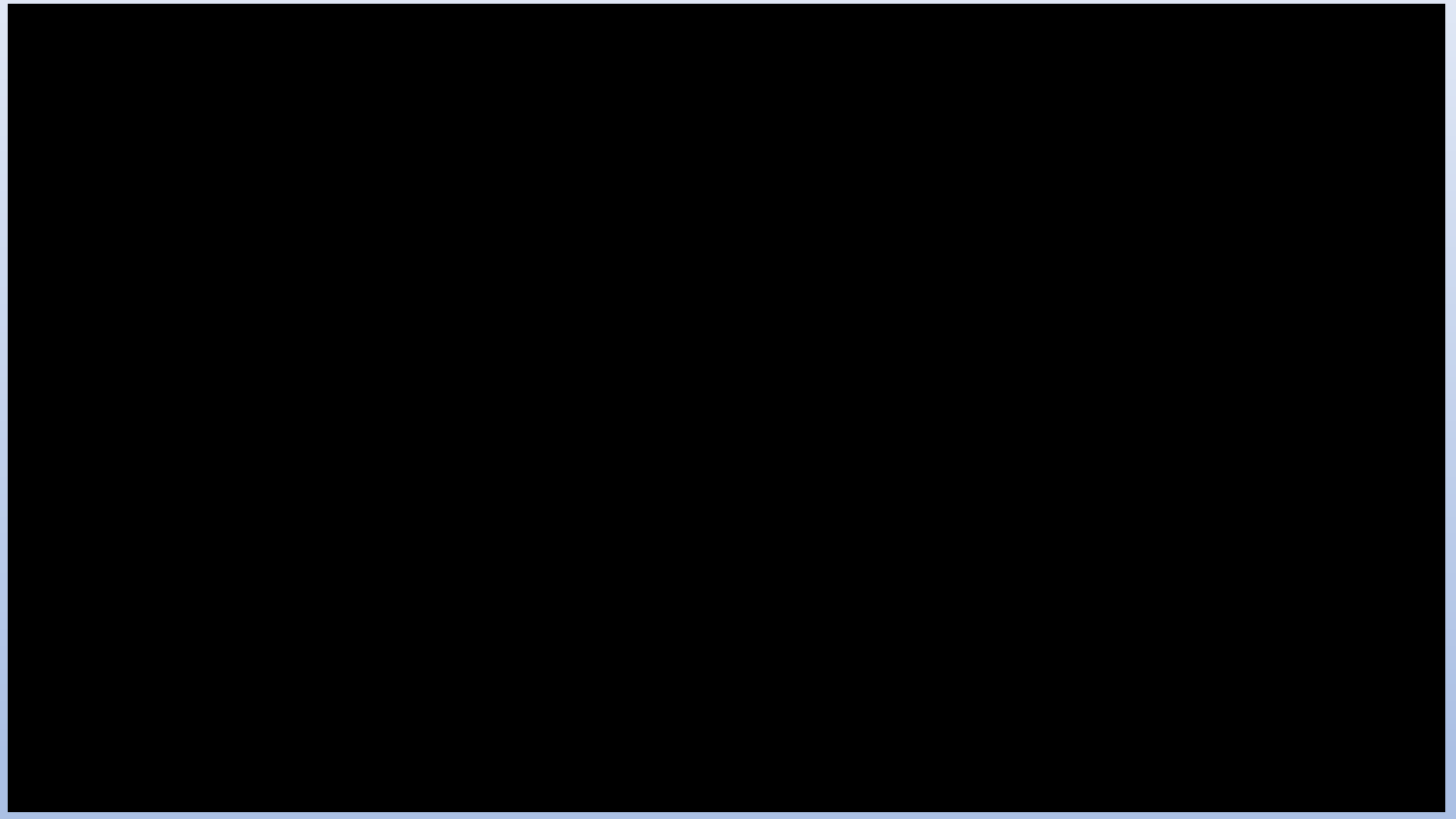
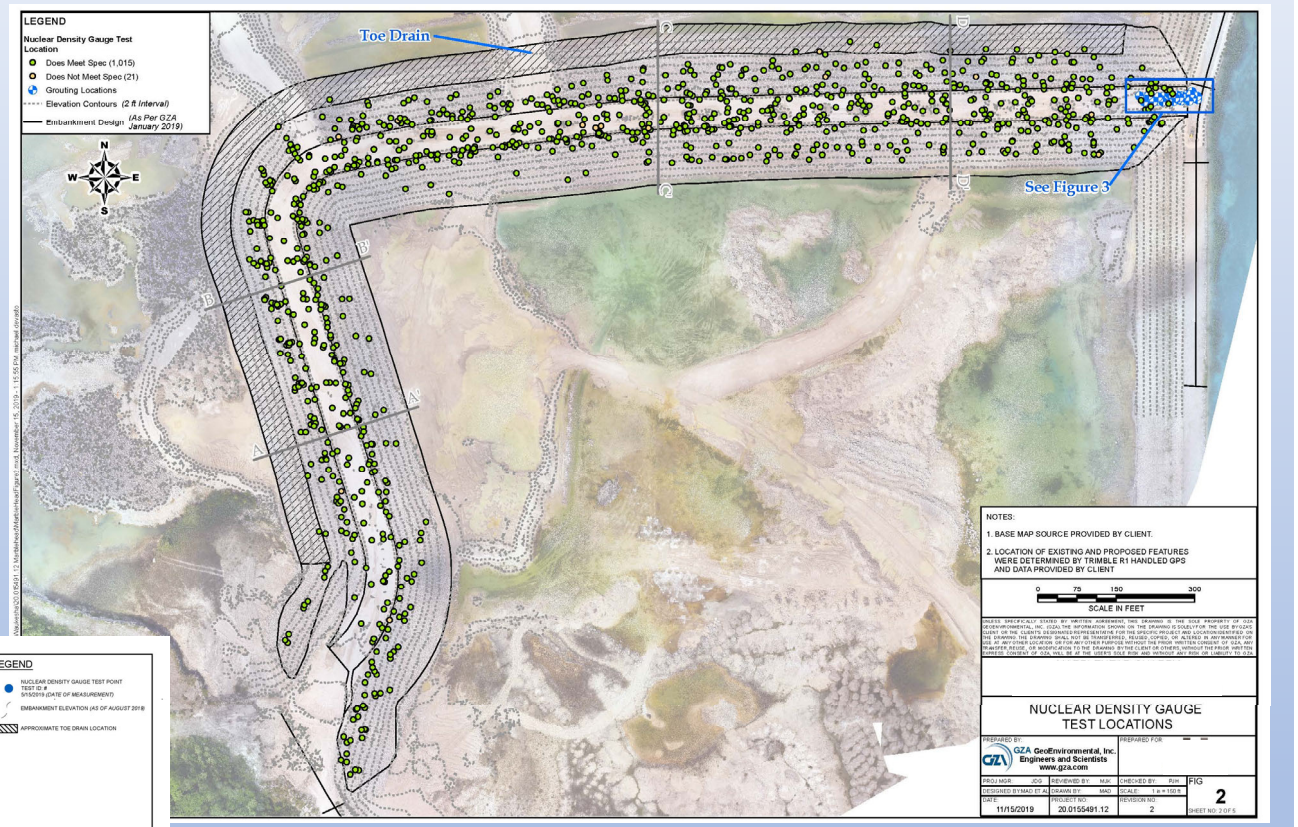
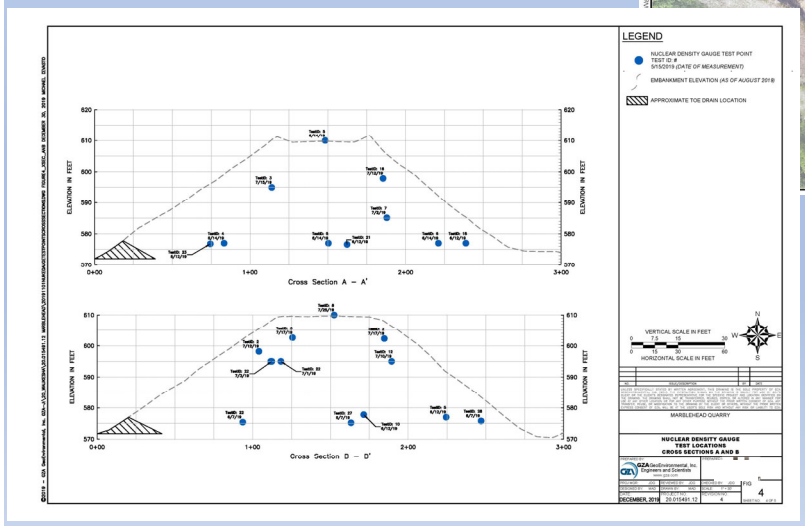
OPENING EMBANKMENT NOTCH



CONSTRUCTION OVERSIGHT & MONITORING

CONSTRUCTION DOCUMENTATION





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RESPONSIBLILTIES

THE OWNER

- Inspection, operation and maintenance and consequences of failure

REGULATORY AGENCIES

- Developing design standards
- Issuing permits
- Enforcing regulations

WHAT SHOULD I BE DOING?

Or the Never-Ending Duties of an Embankment Owner

- Perform informal and formal inspections (i.e. daily, weekly, monthly)
- Special cases: prior to, during, and after major weather events including rain, snowmelt, and/or wind
- Develop an O&M Plan
- Develop an EAP (if necessary or prudent to do so)

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EMBANKMENT INSPECTION BASICS

- What should we look for?
- Where do I start?

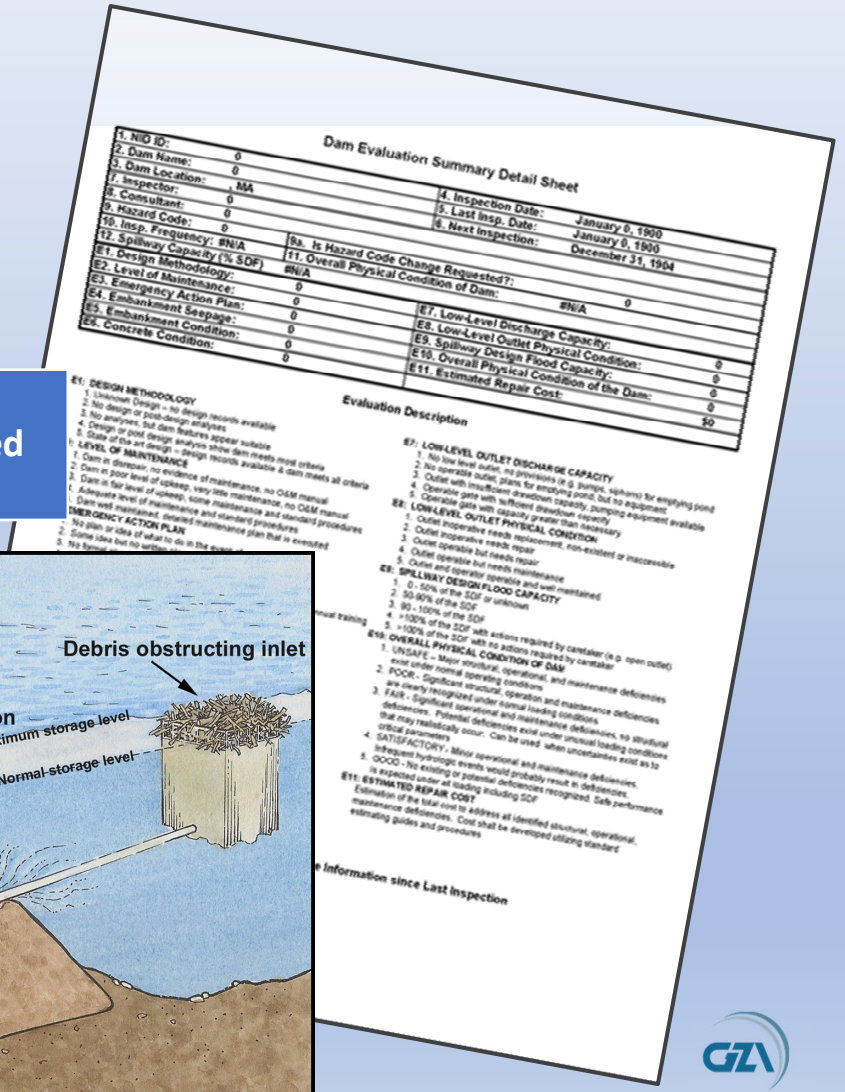
EMBANKMENT INSPECTION LEVEL OF EFFORT

INITIAL INSPECTION

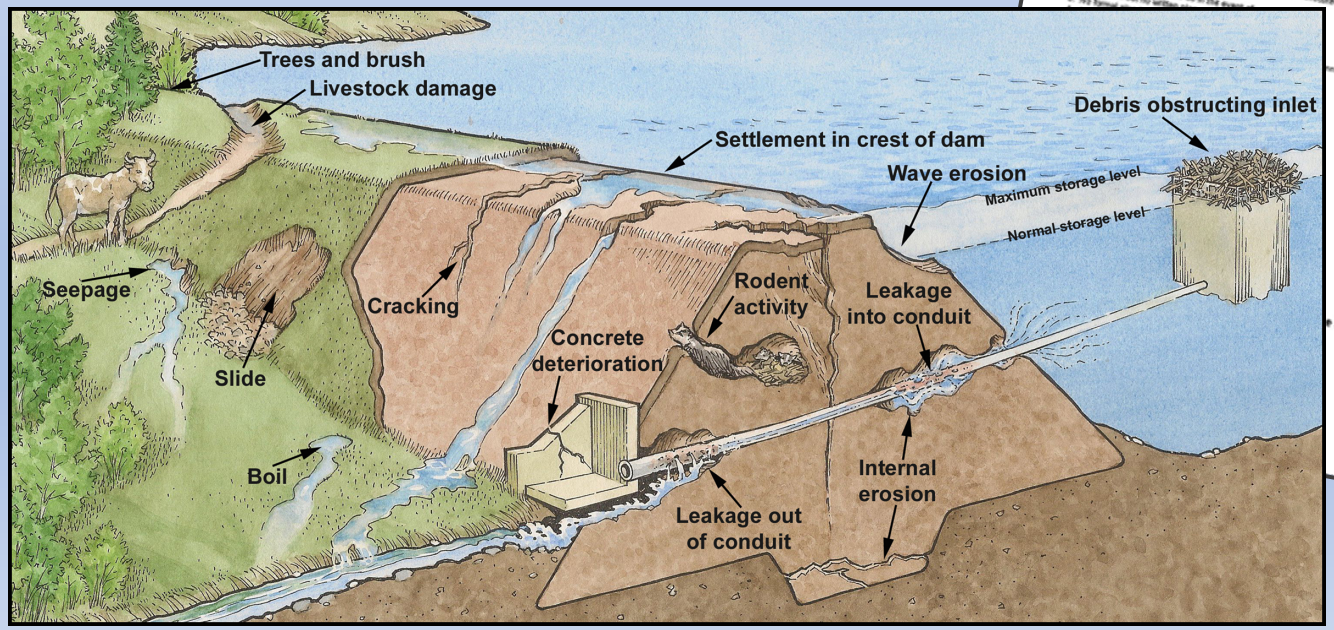
- Review Existing Information
- Visual inspection
- Some engineering evaluation, i.e. stability, spillway capacity?
- Evaluate findings & recommendations

DAM INSPECTION CHECKLIST

- Look for changes
- Document conditions (notes and photos)
- Use a standardized checklist


Dam Evaluation Summary Detail Sheet

Evaluation Description



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EMBANKMENT INSPECTION – WHAT TO LOOK FOR

TOE SEEPAGE

CRACKING

SLOPE FAILURE

OVERTOPPING

EMBANKMENT INSPECTION – WHAT TO LOOK FOR

TREES

SINK HOLES

LEAKAGE

STRUCTURAL MOVEMENT

EMBANKMENT INSPECTION – WHAT TO LOOK FOR

ANIMAL BURROWS

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TYPICAL EMBANKMENT O&M

- Vegetation maintenance
- Animal control
- Exercise of gates, values and pumps
- Clearing of sediment and debris
- Instrumentation monitoring/data collection
- Water level monitoring
- Vandalism, dam access, and security

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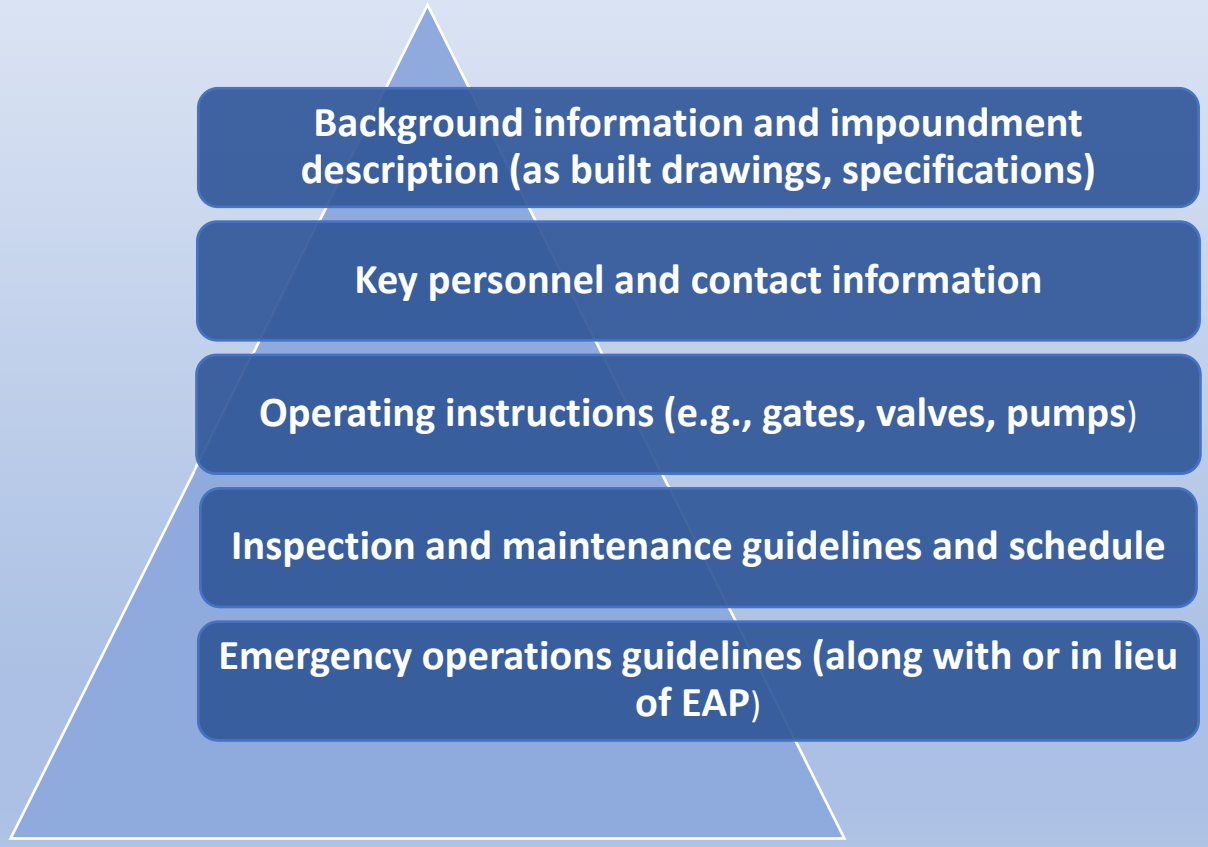
O&M PLAN CONTENTS



EMBANKMENT CARETAKER

One primary person is designated to maintain information and act as embankment caretaker/liaison

Keep a binder with:

- Construction information, photos and plans
- Maintenance records
- O&M Plan
- EAP
- Inspection Checklist
- Other Relevant Documents

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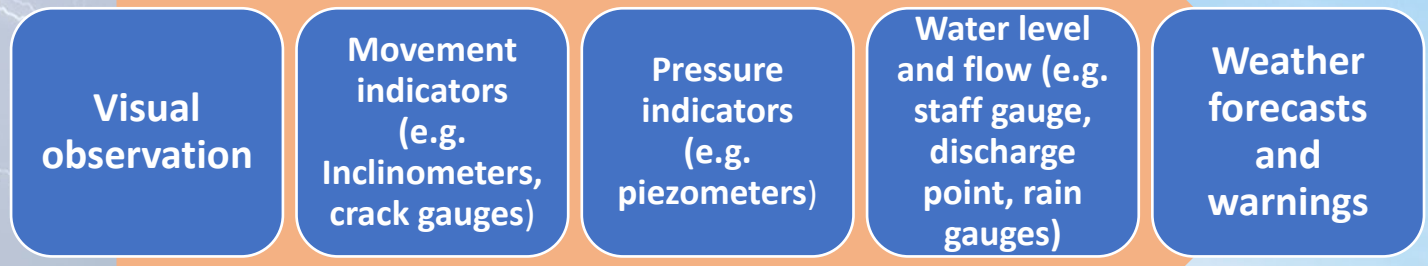
YOUR EMBANKMENT ALARM SYSTEM

- To verify if a dam is performing as intended, and to identify changing conditions, the following should be performed:



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Thank You!
Questions ?

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