CD-4 Hydrology Overview

Submitted to

ConocoPhillips

Submitted by

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Contents

CD-4 HYDROLOGY OVERVIEW

1.0 Walker and Arnborg

- Hydrologic investigation of the Colville Delta region started as early as 1961 when H. J. (Jesse) Walker presented his findings on work in the Delta at the First National Coastal and Shallow Water Research Conference
- Walker's early work was aimed at exploration and characterization of the little-known Delta
- Walker and Arnborg went on to investigate many different aspects of the hydrology of the Colville Delta
- Walker and Arnborg's work on the Delta represents the most comprehensive work done to date and is still a valuable and often-used resource
- Walker and Arnborg's work forms a solid foundation for modern day investigations
- Conclusions and observations that they made are still valid and have been useful in our understanding of topics as diverse as river bank erosion, channel migration, sedimentation and sediment transport, discharge, and permafrost

2.0 Recent Spring Breakup Monitoring

- 1992-1996: ABR and Shannon & Wilson completed geomorphological and hydrological investigations
- 1997: Michael Baker Jr. (MBJ) teamed with Shannon & Wilson studying spring breakup on the project
- In 1998, MBJ took over the spring breakup investigation and has since performed the project annually including the 2004 monitoring
- Since 1998, calculation of peak discharge at Monument 01, the "Head of the Delta" has always been a cornerstone of the spring breakup program

2.1 Design Flood

The design flood was selected based on several reasons:

- Most major river projects designed by the US Army Corps of Engineers are based on the Standard Project Flood. The Standard Project Flood is a theoretical flood assumed to have a 1 in 200 probability of occurring in any given year (0.5% chance)
- Alaska Department of Transportation and Public Facilities (ADOT/PF) uses a 50-year design flood for primary and important secondary highways and bridges

- Design life based on a range of 2.5 to 5 times the design life for the facility. Based on a 20-year design life, a range of 50-100 year design flood is appropriate.

2.2 CD-4 Pad

- Location as per reservoir considerations
- Minimum pad fill height as per thermal reasons and freeboard above design flood water elevations
- Design flood water elevation determined by 2-D modeling

2.3 CD-4 Road – Elevation

- Alignment for most part follows height of land
- Minimum fill thickness of 5 feet for thermal reasons
- For majority of route, resultant height is well above 200-year water level
- Design flood water elevation determined by 2-D modeling

2.4 CD-4 Road – Openings

- Cross flow can be East-West or vice versa
- No defined channels
- Openings not needed for hydraulic reasons, as vast majority of flow is parallel to the road
- Paleo Channel road openings have been monitored and considered specifically since 2000

3.0 2-Dimensional Modeling for Colville River Delta Facilities

3 methods were considered for developing design water surface elevations at facilities in the Colville River Delta

- Normal Depth (plus or minus 4 or 5 feet)
- 1-Dimensional Modeling (plus or minus 2 feet)
- 2-Dimensional Modeling (plus or minus 1 foot)

3.1 Selection of 2-Dimensional (2D) model

In 1996, the 2-Dimensional (2D) model method was selected as the preferred method

- Jim Aldrich / Shannon & Wilson Method Selection
- Expected accuracy of predicted water surface elevations

- Expected considerable regulatory review
- The 2D Model was the most capable of effectively addressing flow in the large number of distributary channels

3.2 2D Surface Water Model Overview

- The 2D Model is a product of two computer programs and a considerable data collection effort
- The finite element mesh is developed, and results are analyzed, using the Surface Water Modeling System (SMS) Program, developed by Brigham Young University
- Numerical computations are performed using Finite Element Surface-Water Modeling System: Two-Dimensional Flow in a Horizontal Plane (FESWMS)
- A topographic base map was used to develop the finite element mesh
- Values for hydraulic roughness were then assigned to each of the elements in the mesh
- Water surface elevation was used to describe the downstream boundary condition
- Total discharge was used to describe the upstream boundary condition

3.3 Original Intent of Model

- Developed to predict peak water surface elevations and velocities for large flood events (50-, 100- and 200-year)
- Used to estimate the impact facilities would have on the environment with respect to large spring floods
- Ice effects to water surface elevation will be minor during large flood events

4.0 Historical CD-2 Culverts and Bridges peak discharge rates

The following table of peak discharge values for CD-2 culverts and bridges represents the hydraulic significance of the existing culverts in the CD-2 road. During the relatively high-water breakup events of 2000 and 2004, the average discharge for each culvert in the CD-2 road is approximately 45 cfs. It is interesting to note that the discharge of the culverts exceeded the discharge through the 62-foot bridge for 2000 and 2004.

Breakup Year	Peak Discharge				
	CD-2 Culverts			62-foot bridge (cfs)	452-foot bridge (cfs)
	Discharge (cfs)	Culverts flowing	Average Discharge		
2004	1191	25	48	800	3400
2003	22	2	11	0	730
2002	195	9	22	500	4000
2001	280	13	22	620	3900
2000	982	24	41	975	7085

Design Considerations used in the construction of the CD-2 Culverts included:

- Gravel road prism is frozen during the peak spring breakup event
- Rip Rap side slope protection around the entrances and exits of all culverts
- Articulated concrete mat with geotextile underlayment on the tundra at all downstream culverts exits
- Midpoint steel seepage ring installed on all culverts in order to protect culvert and road from water migration and piping along culvert
- Installation of culvert bedding and insulation beneath each culvert to provide for sound culvert foundation
- Plywood culvert end caps to prevent snow and ice accumulation in the culvert during the winter. A technique that is extremely successful in assuring maintenance of culvert hydraulic capacity.
- Road side slope erosion protection included vegetation and jute mat

Twenty-six culverts have been in place in the CD-2 road since the summer of 1999. The culverts have withstood five spring breakup floods without a single culvert failure or any significant sign of culvert degradation or erosion. The CD-4 culverts will be subjected to similar conditions and will perform with similar success.

5.0 Alpine and CD-4 (CD-South) Monitoring Observation Reports Summary

1999

- 1999 Spring Breakup and Hydrologic Assessment Colville River Delta, November 1999

2000

- 2000 Spring Breakup and Hydrologic Assessment Nechelik Channel, Colville River Delta, Alaska for CD-South Development Project, January 2001. In addition to ice and water elevation observations and photography at CD-4, the report identifies the estimated floodwater inundation along the proposed CD-4 road and at the CD-4 pad.
- Alpine Facilities Spring 2000 Breakup Monitoring Alpine Development Project, November 2000

2001

- Alpine Facilities 2001 Spring Breakup and Hydrologic Assessment, August 2001
- CD-South Development Project 2001 Spring Breakup and Hydrologic Assessment, September 2001. In addition to ice and water elevation observations and photography at

CD-4, the report identifies the surface water cross-flow patterns along the proposed CD-4 road and at the CD-4 pad.

2002

- Colville River Delta Two-Dimensional Surface Water Model CD-Satellite Project Update, May, 2002
- CD-South Bank Migration Analysis, May 2002
- Alpine Facilities 2002 Spring Breakup and Hydrologic Assessment, October 2002
- CD-South Development Project 2002 Spring Breakup and Hydrologic Assessment, November 2002. In addition to ice and water elevation observations and photography at CD-4, the report identifies the surface water cross-flow patterns along the proposed CD-4 road and at the CD-4 pad.

2003

- Alpine Facilities 2003 Spring Breakup and Hydrologic Assessment, September 2003

2004

- Preliminary Findings, Colville River Delta Two-Dimensional Surface Water Model Nigliq Channel Bridge Project, March 2004
- CD-4 Road high-water mark field survey, June, 2004
- CD-4 Road East/West Cross Drainage Project Note, July 2004
- CD-4 Road Culvert Capacity for Fish Passage Project Note (Baker and PND) September 2004
- DRAFT Alpine Facilities 2004 Spring Breakup and Hydrologic Assessment, October 2004

6.0 CD4 Culvert Conclusions

The majority of the proposed CD4 road alignment is situated on a relatively high ridge that is a natural barrier between the flood plain on the east and west side of the road. The concern regarding drainage structures has primarily been limited to the southern portion of the road as the road alignment crosses the paleo channels located to the north and south of Lake 9323. Based on the volume of water observed during CD3 specific hydrologic investigations beginning in 2000 in conjunction with hydraulic modeling of the facilities, culvert batteries were determined to be the most appropriate method of providing cross drainage through the proposed road. This has been found to be the case for the following hydraulic reasons:

1. Natural water levels during non-breakup events do not warrant a bridge as the paleo channels are essentially dry during the majority of the year

2. During mean annual breakup flood events based on field observations and 2-d hydraulic modeling, the volume of water flowing at either paleo crossing is relatively minor and in line with the hydraulic capacity of the proposed culverts

3. During design flood events, velocities in the paleo channel are very small. Therefore the amount of water flowing in the paleo channels is insignificant compared to the volume of water flowing in either the Sakoonang or the Nigliq Channels

4. During design flood events, the culverts structurally will perform well based on improved design standards and the success of the CD2 culverts for passage of water since 1999