Probabilistic Alternatives Analysis of Regional Sediment Management Practices

A Presentation To:

The National Conference On Beach Preservation Technology

Presented By:

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Introduction

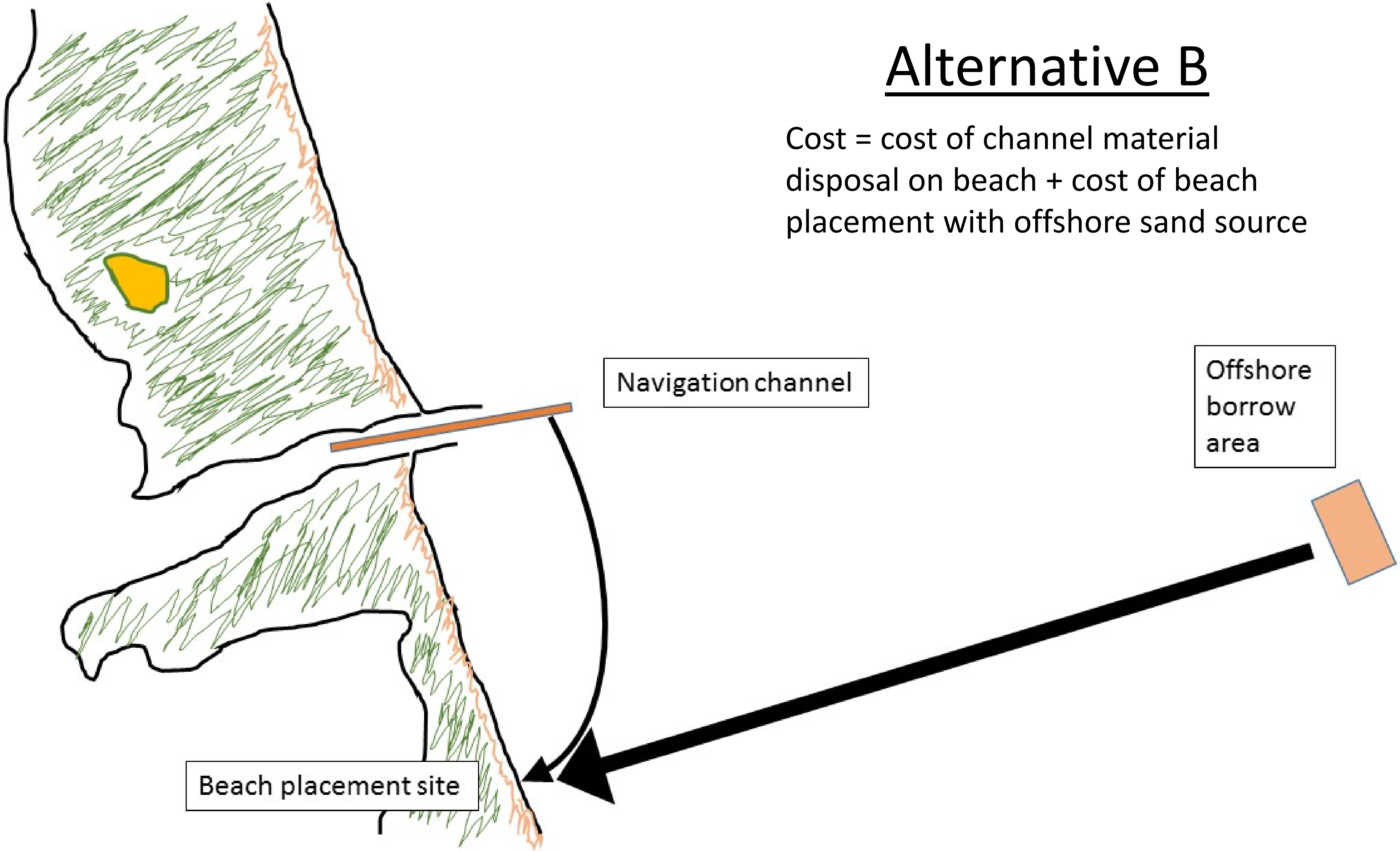
- Purpose – present a probabilistic simulation model to investigate the potential difference in costs associated with placing dredged navigation channel material on adjacent nourished beach (and nourishing same beach with offshore material) compared to disposing dredged navigation channel material upland (and nourishing beach with offshore material)
- Model – simulate filling and dredging of navigation channel and erosion and placement of beach fill project based on probabilistic inputs and Monte Carlo simulations

Introduction

- Motivation – While regional sediment practices (RSM) seem like a win-win situation, does implementing it provide cost savings from a regional perspective?
- Goal – Determine if the costs associated with placing offshore sand and dredged channel material on the beach is equal to or less than the costs associated with nourishing the beach with offshore sources alone and disposing of channel material upland.

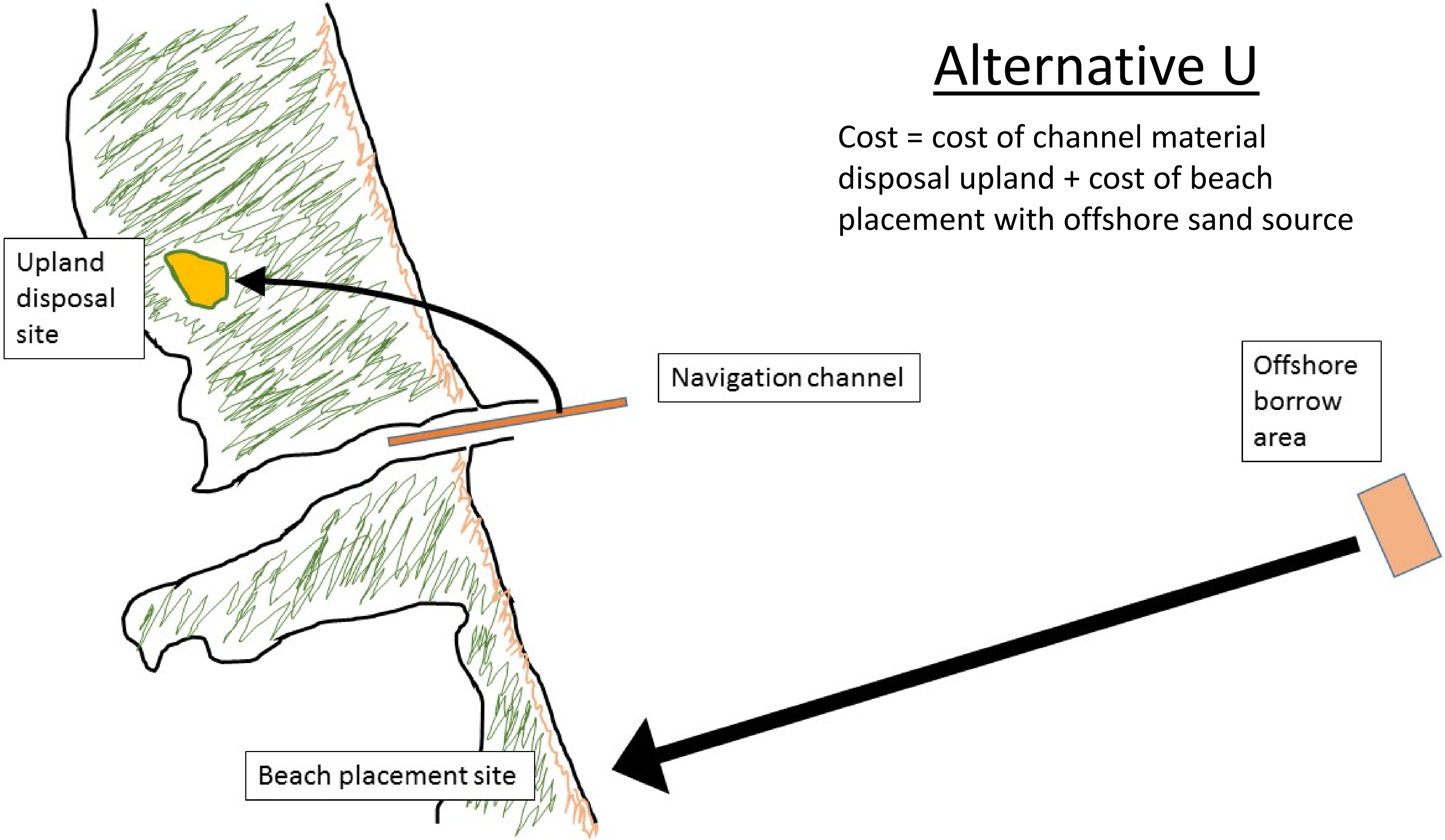
Alternative B

Cost = cost of channel material disposal on beach + cost of beach placement with offshore sand source



Alternative U

Cost = cost of channel material disposal upland + cost of beach placement with offshore sand source



Overview

- Begin with dredged channel and nourished, equilibrated beach
- Channel infills as result of intercepting annual longshore sediment transport
- Beach erodes via background erosion, longshore spreading, and storm-induced erosion
- Once dredging threshold met or exceeded, channel reverts back to initial, dredged condition

Overview

- Dredged channel material placed on beach (Alt B) or upland (Alt U)
- Calculate and record channel dredging cost (based on Alt B or Alt U)
- Increase beach width based on received channel material (if any)
- Once beach erosion threshold met or exceeded, beach reverts back to initial, nourished condition
- Calculate and record beach fill construction cost
- Run simulation for multiple 50-yr scenarios for both alternatives

Model – Navigation Channel

- Define channel by initial depth (z), width (W), and length intercepting longshore sediment transport
- Vary longshore sediment transport by normal distribution
- Vary overdredge depth by triangular distribution to account for dredging variability
- Applied Kraus and Larson (2001) method
  - Simulates channel infilling by intercepting longshore sediment transport and adjusting channel depth and width accordingly
  - Neglects sediment transport by flood and ebb tidal currents

Model – Nourished Beach

Kriebel (2008)

- Define rectangular fill with length (L), width (B), berm height, depth of closure (DoC), equilibrium shape parameter (A), and beach slope
- Except DoC, vary these variables by normal distribution to account for variability during beach construction
- DoC, defined by annual mean wave height
- Vary mean wave height by normal distribution
- Beach somewhat different every time renourished

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Model – Beach Erosion

Kriebel (2008)

- Background erosion rate
  - Normal distribution
- Longshore spreading of beach fill
  - Coastal Engineering Manual (CEM) analytical solution for rectangular beach fill (depends on beach length and diffusivity parameter)
  - Diffusivity parameter proportional to mean wave height, berm height, and DoC (all normally distributed random variables)
- Storm-induced erosion
  - Kriebel and Dean (1993) and CEM
  - Time dependent erosion based on storm surge height, duration, breaking wave height, and beach profile parameters described previously
  - Storm surge height, duration, and breaking wave height vary by normal distribution and storm type (e.g., northeaster or hurricane)

Model – Some assumptions

- Unlimited supply of offshore sand resources (from site a fixed distance offshore)
- Unlimited storage capacity of upland disposal site (a fixed distance from channel)
- Shoaled material in channel is beach compatible and placed along beach uniformly
- Beach nourishment triggered when less than 10% of beach width remains
- Channel dredging triggered when less than 75%-80% dredged channel depth or width remains
- Construction costs include mobilization plus dredging or beach fill quantity costs plus 10% of total costs (mob + quantity costs) to account for environmental monitoring (and other misc. costs) during construction
- Year 1 = 2016
- Inflation rates originated from www.bls.gov/cpi
- Discount rate = 4%

Application – Northeast Florida

Parameter – Normal Distributions	Mean	Std dev
LSTP (cy/yr)	200,000	-250,000
"A" parameter (m^1/3)	0.125	0.015
Beach berm height (ft)	11	0.5
Beach slope (1V:xH)	15	100
Background erosion rate (ft/yr)	-1.5	1.5
Mean annual wave height (ft) (WIS statistics)	4.0	0.3
Peak storm surge durations (nor./hur.) (hours)	30/12	6/3

Parameter – Triangular Distribution	Most Likely	Min	Max
Overdredge depths (ft)	0.5	0	1

Storm waves

- Based on USACE WIS statistics
    - 1-yr or greater storms
    - 0.6 northeasters per year
    - 0.4 hurricanes per year

Storm surge elevations

- Based on FDEP published reports

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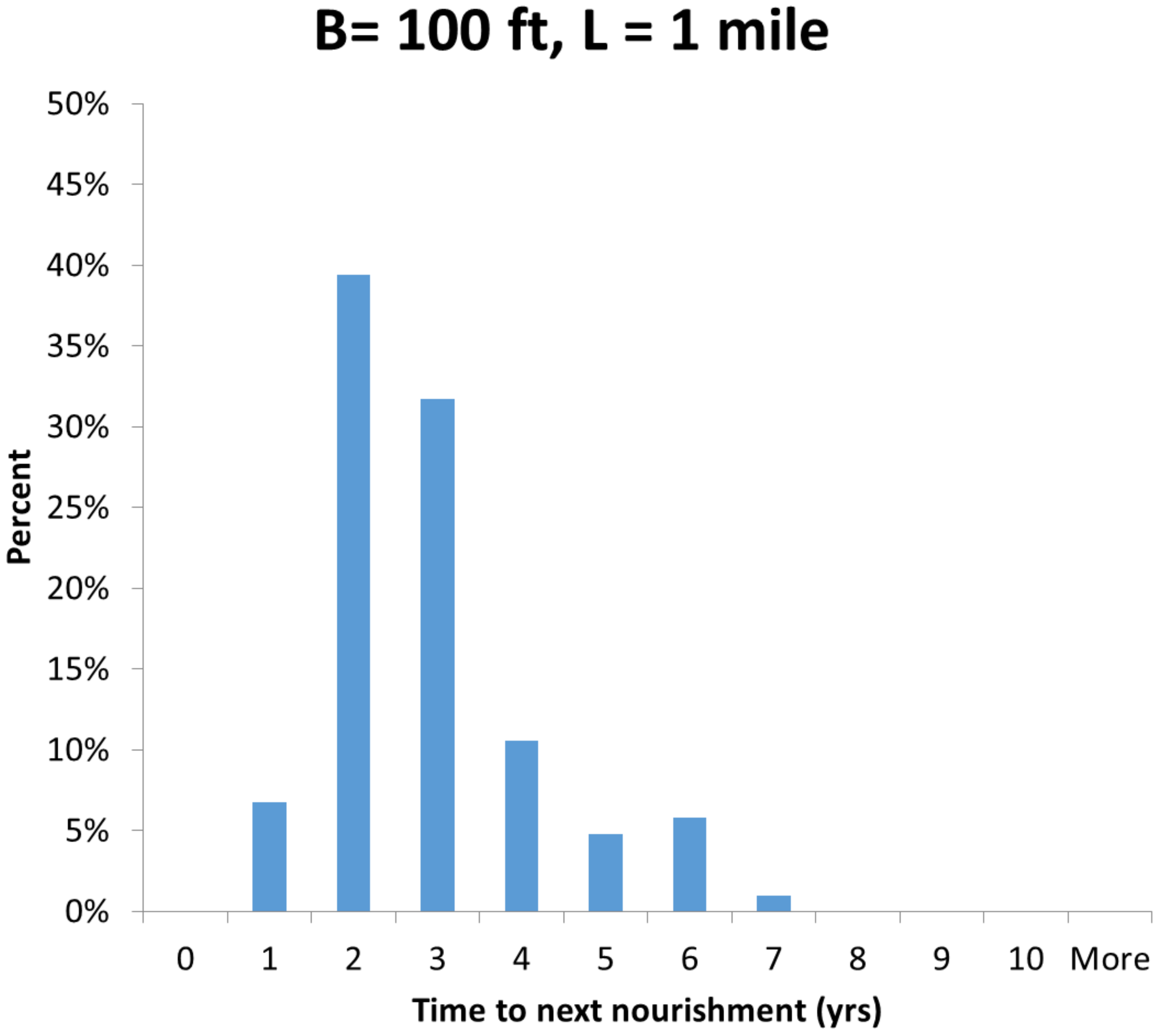
Model Checks

- Variable Beach Length (L)



Model Checks

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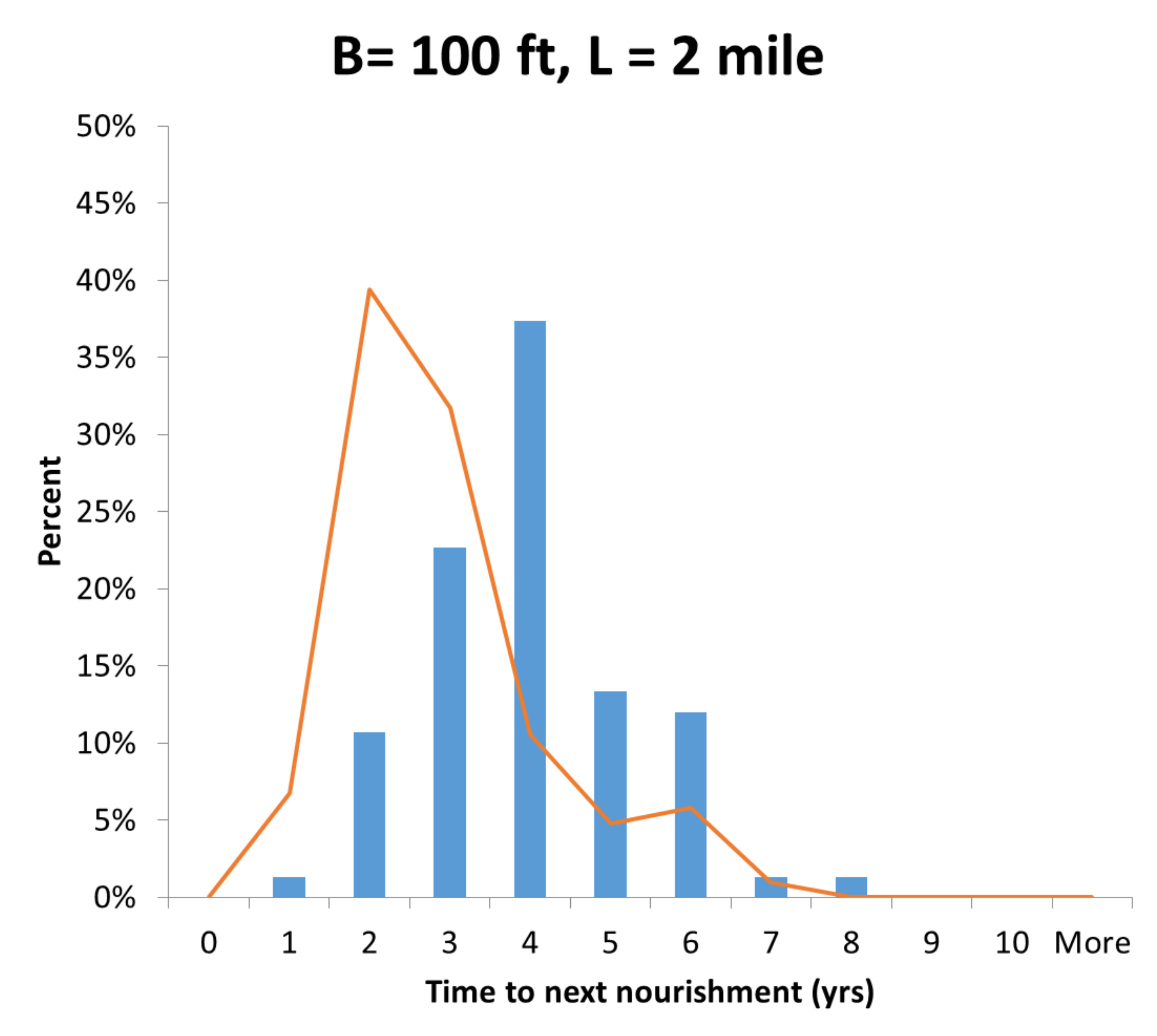

Model Checks

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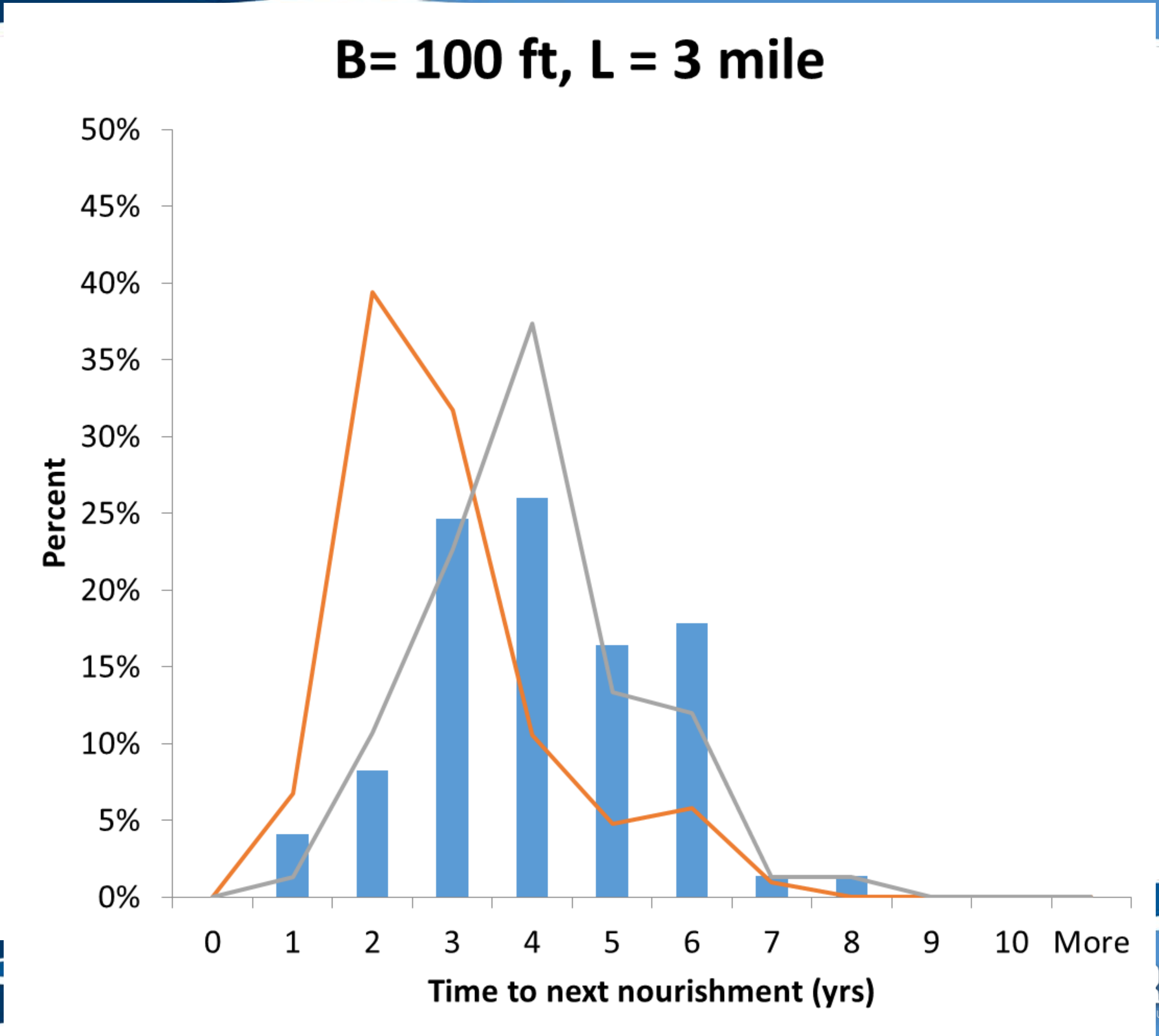
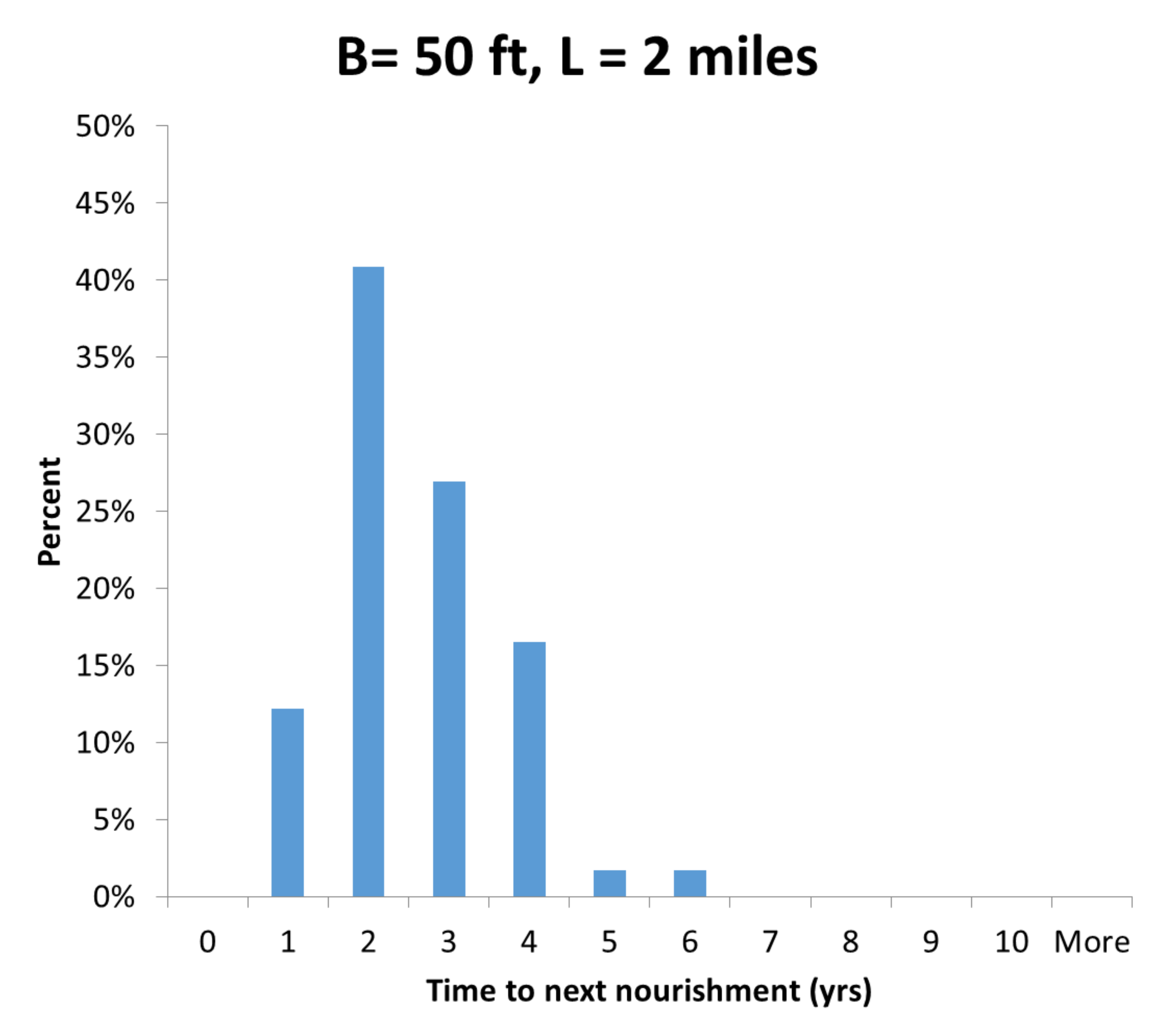


Model Checks

- Variable beach width (B)



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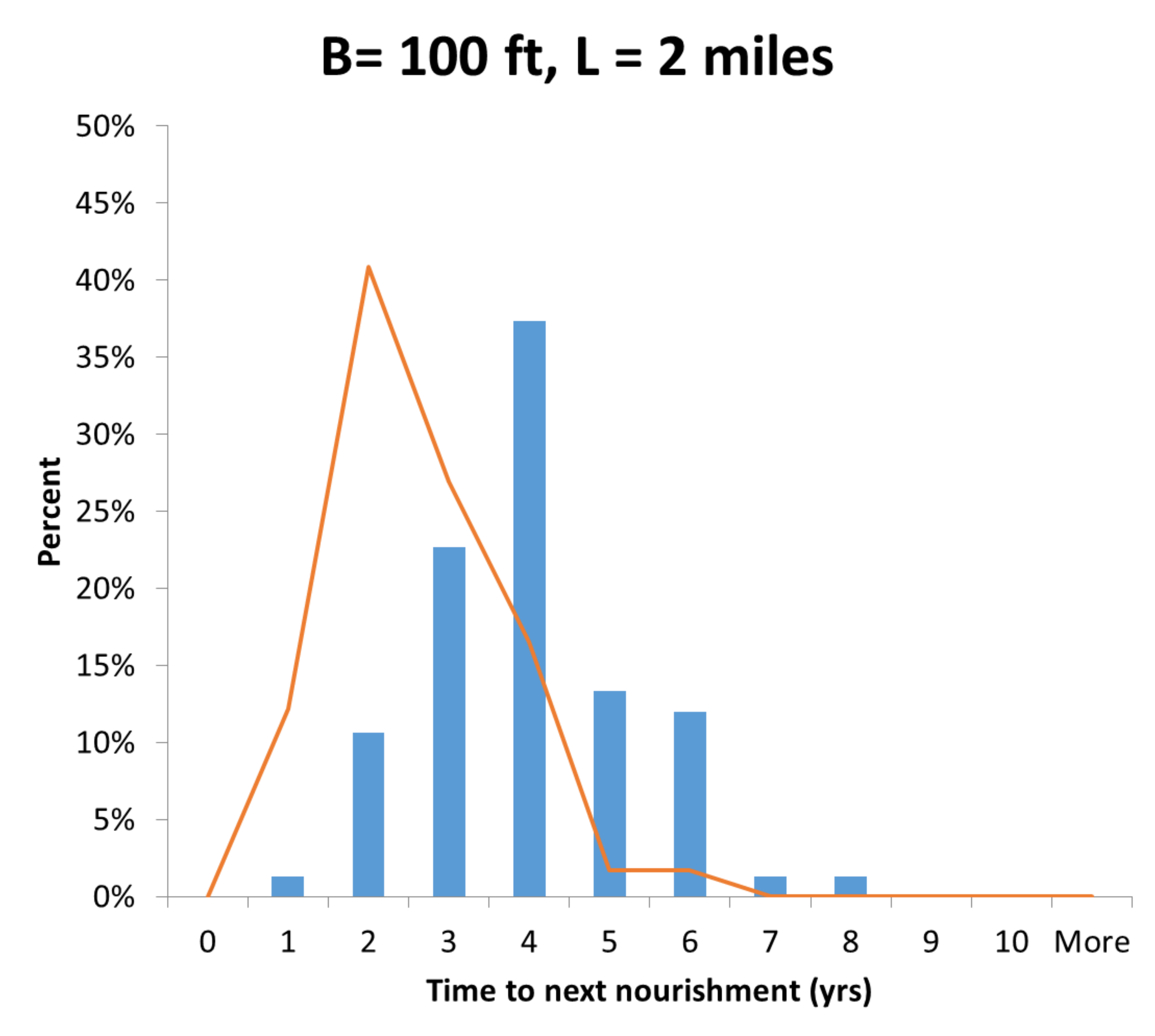

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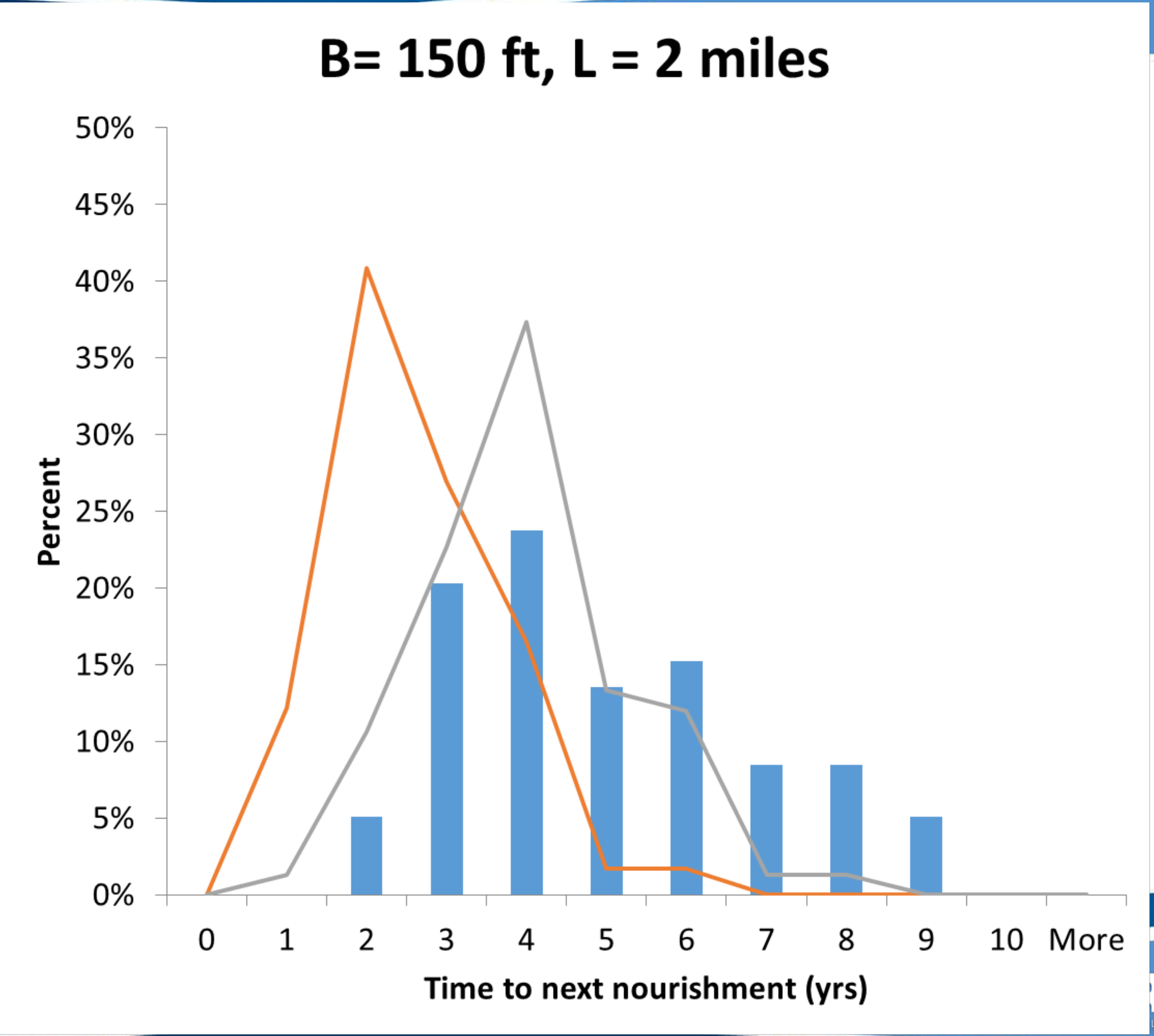
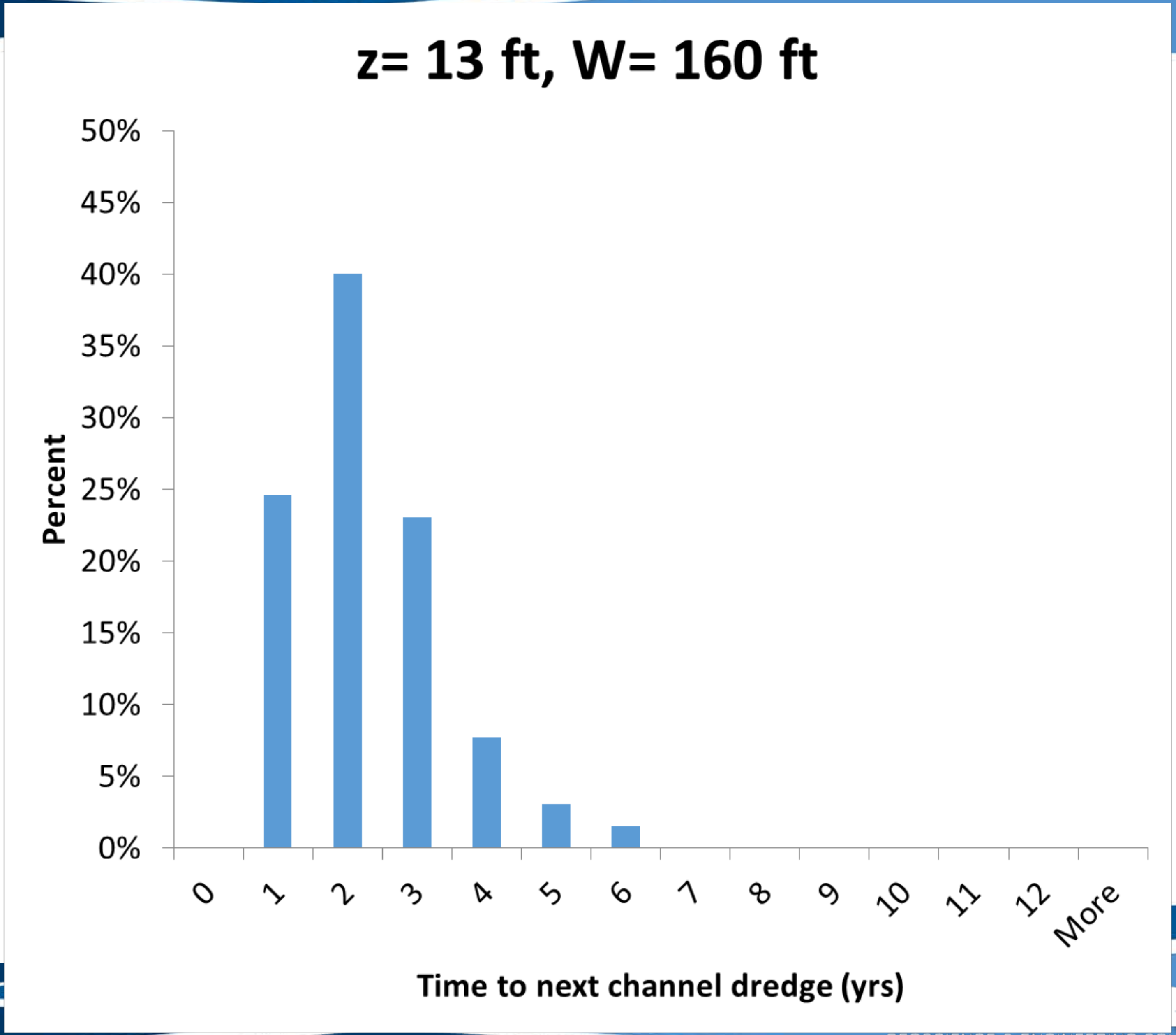


Model Checks

- Variable channel dimensions



Model Checks

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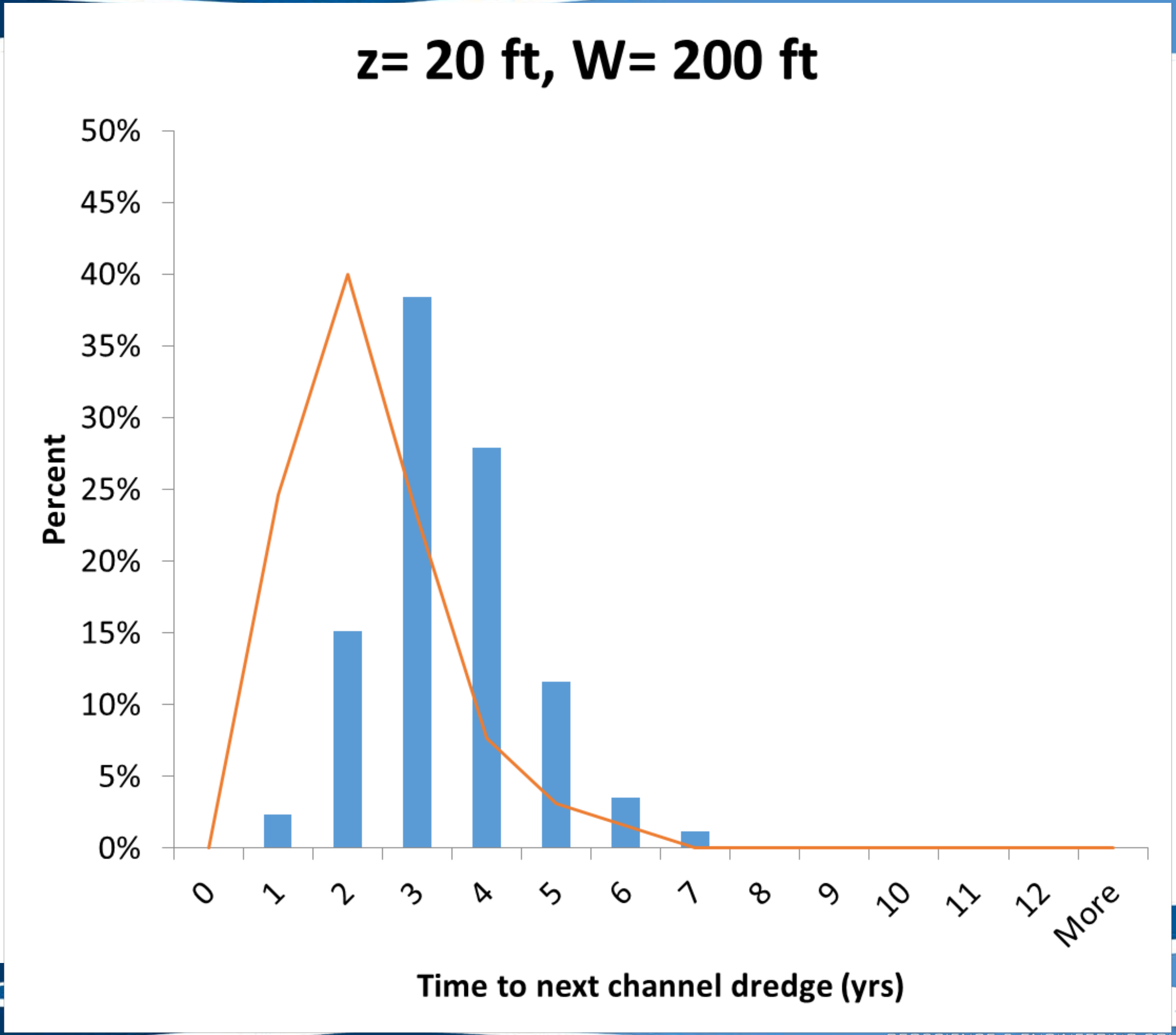

Model Checks

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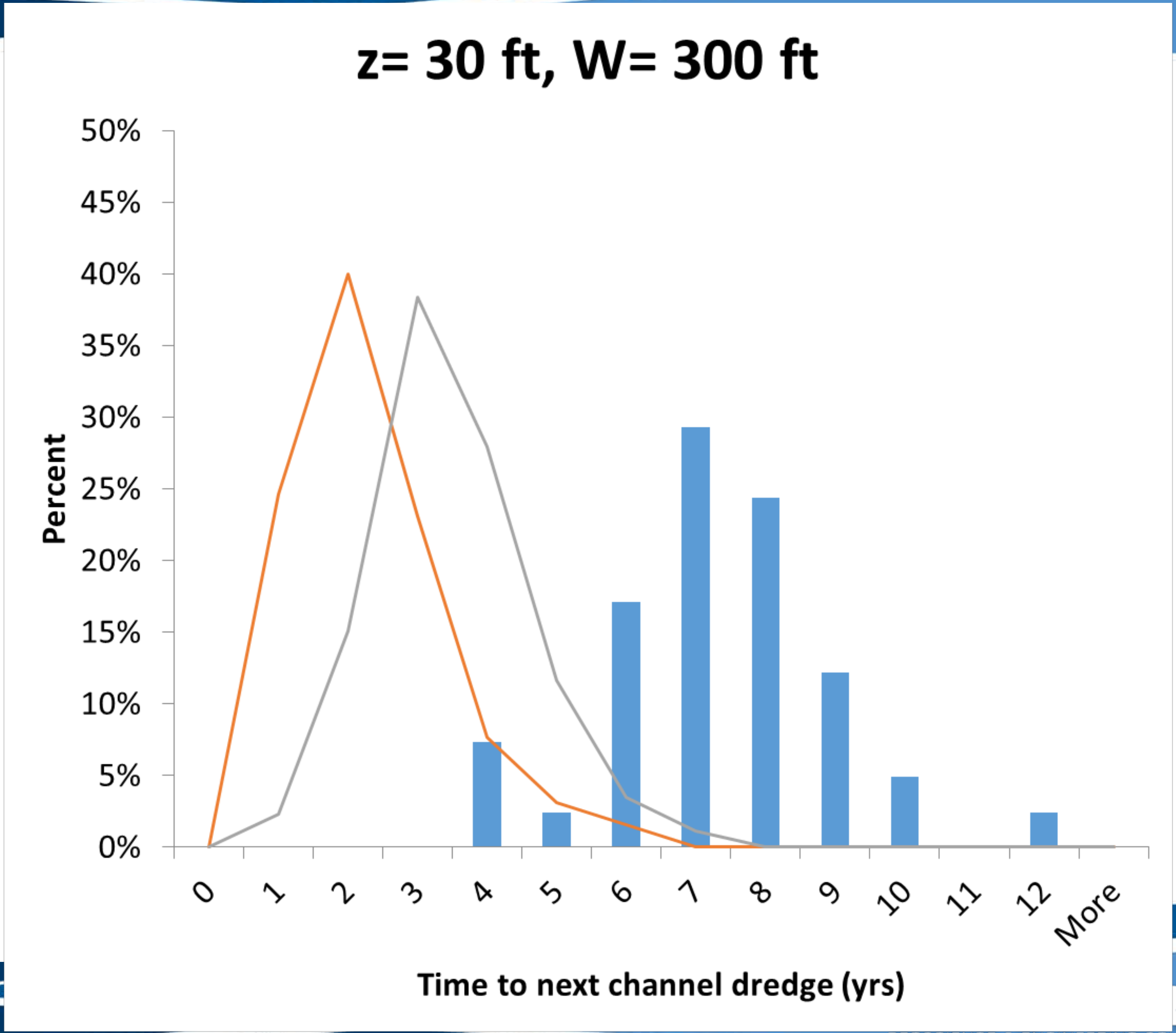


Application - Hypothetical

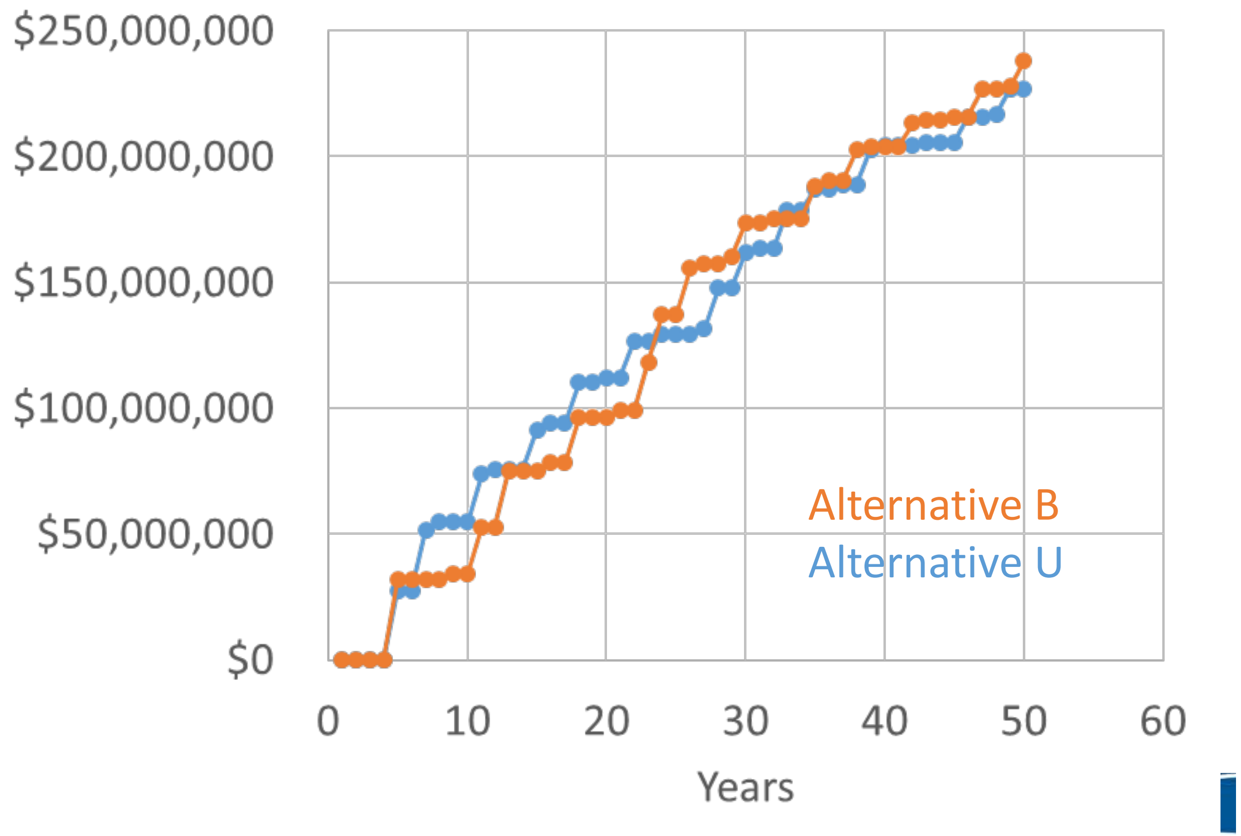
- Project costs
  - Modified normal distribution with maximum and minimum values
  - Channel dredging
  - Beach nourishment
  - Other costs (e.g., environmental) = 10% of sum of mob. + quantity costs
- Simulations
  - Simulated 300, 50-yr periods implementing Alternative B and Alternative U and varying beach fill and channel dimensions

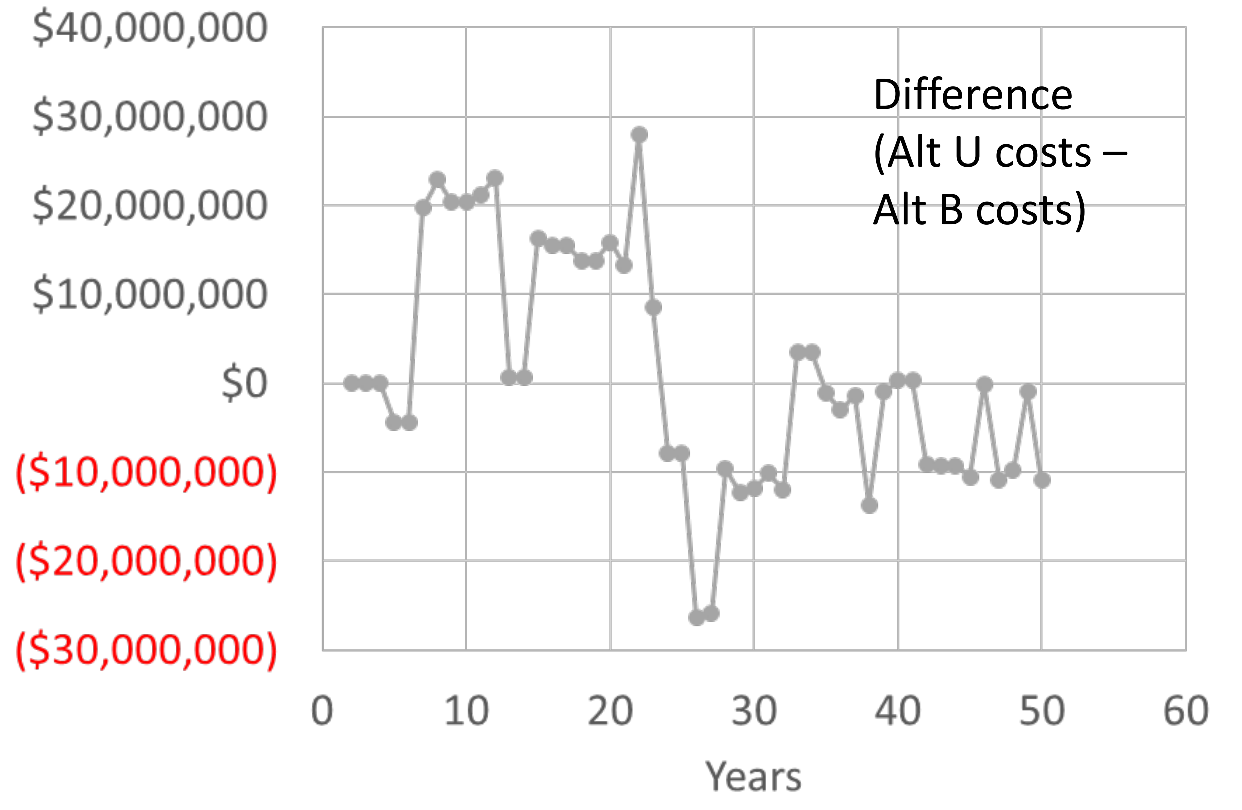
Mobilization	Cost ($)
Mean	$1.8 mil (channel dredging); $2.5 mil (beach fill – offshore)
Std dev	25% of mean
Min	$1 mil
Max	200% of mean

Quantity Based Item	Cost ($/cy)
Mean (adjusted downward by $1 for every 200,000 cy dredged channel and 500,000 cy placed on beach from offshore)	$11 (channel-beach disposal); $8(channel-other disposal); $12.50 (beach-offshore source)
Std dev	25% of mean
Min	60% of mean
Max	180% of mean

Results

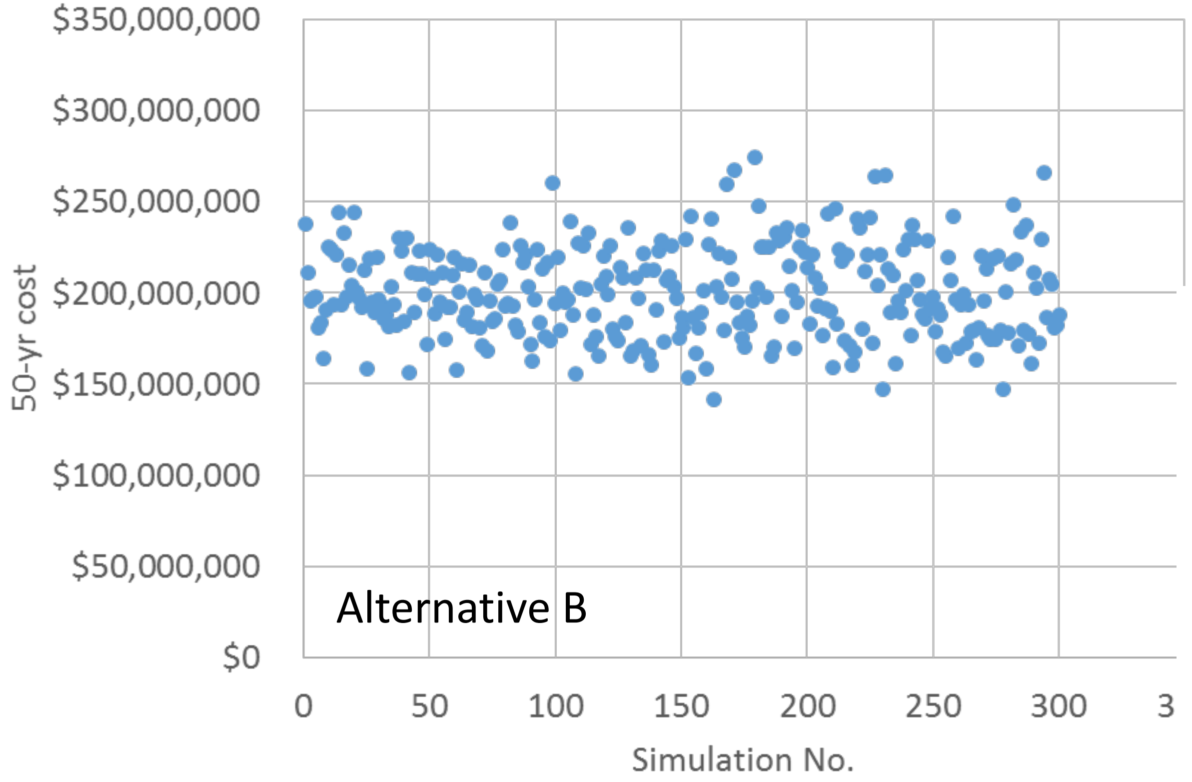
- Sample results – 1 of 300 simulations
  - 50-yr period
  - Beach length = 2 miles and berm width = 100 ft
  - Inlet channel depth = 20 ft and width = 200 ft

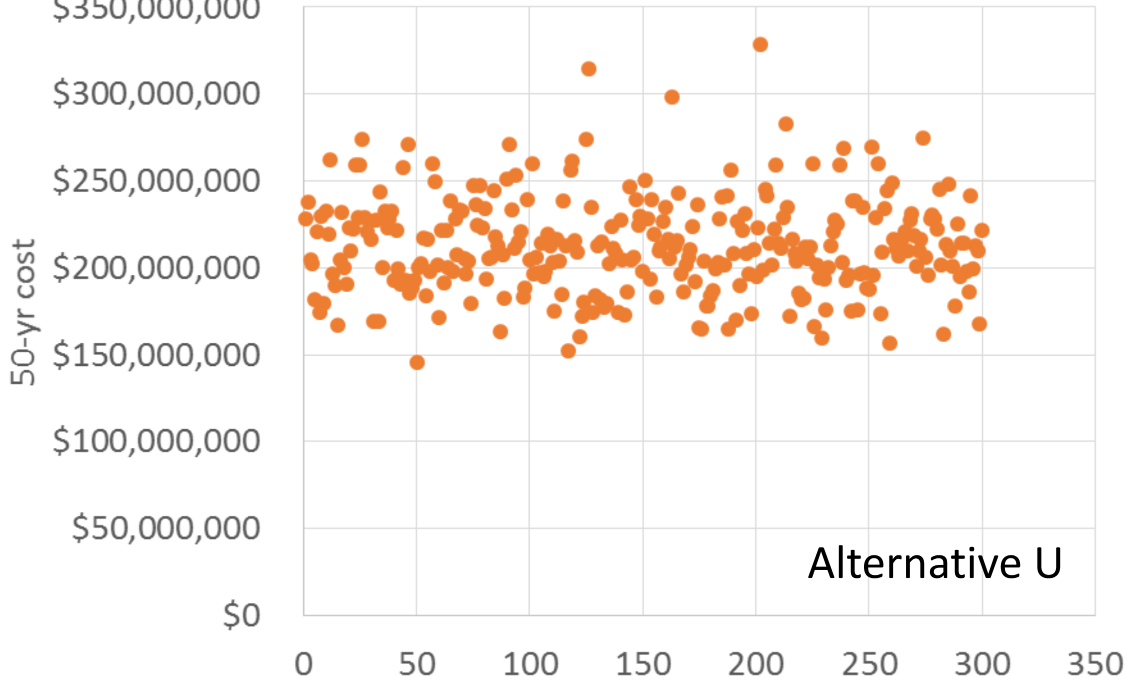


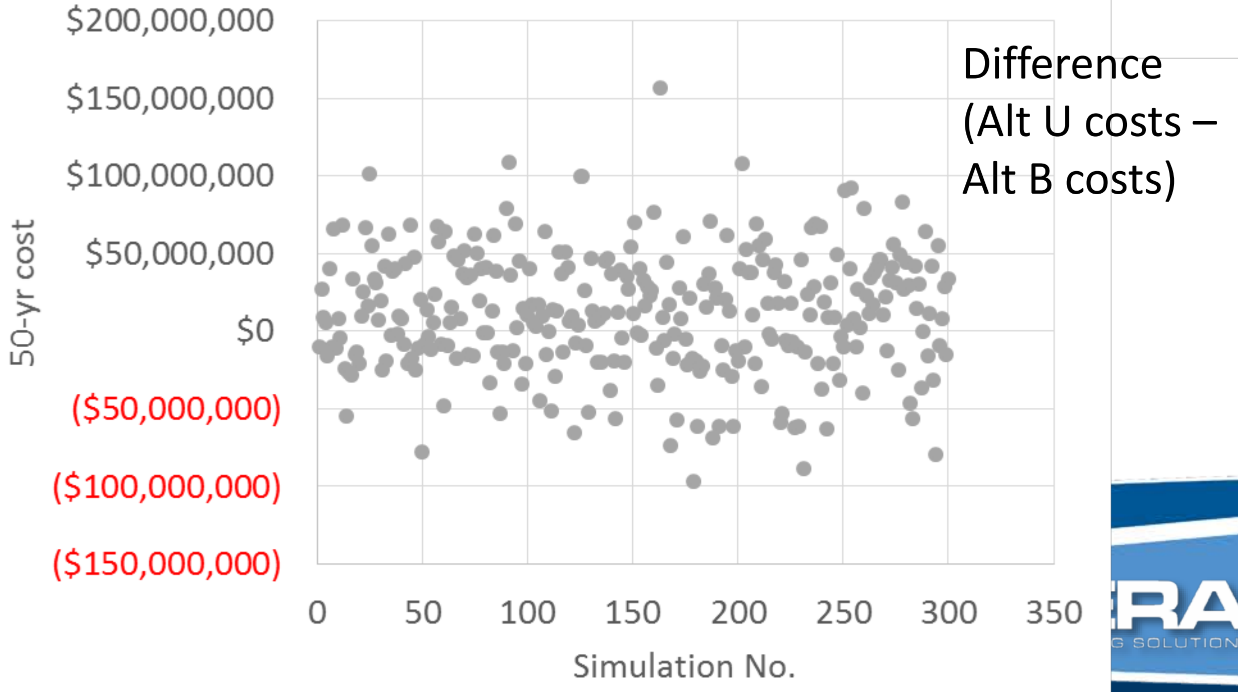


Results

- 50-yr period
- L= 2 miles and B = 100 ft
- z = 20 ft and w = 200 ft





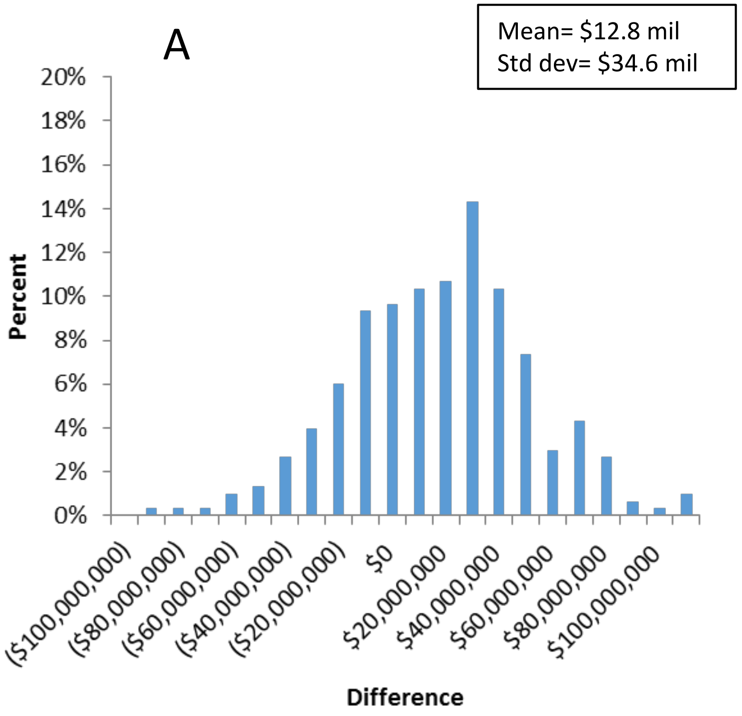


Cumulative discounted present worth costs at end of 50 yrs

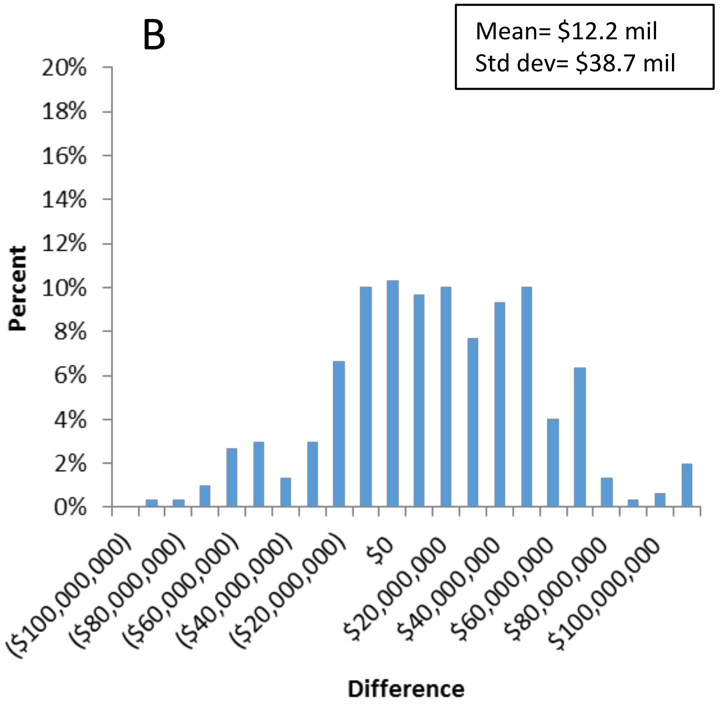
Results – Fixed beach, varying channel

- 300, 50-yr period simulations
- Beach width = 100 ft
- Beach length = 2 miles
- Inlet channel depths and widths vary
  - (A) Depth (z) = 13 ft, width (W) = 160 ft
  - (B) Depth (z) = 20 ft, width (W) = 200 ft
  - (C) Depth (z) = 30 ft, width (W) = 300 ft

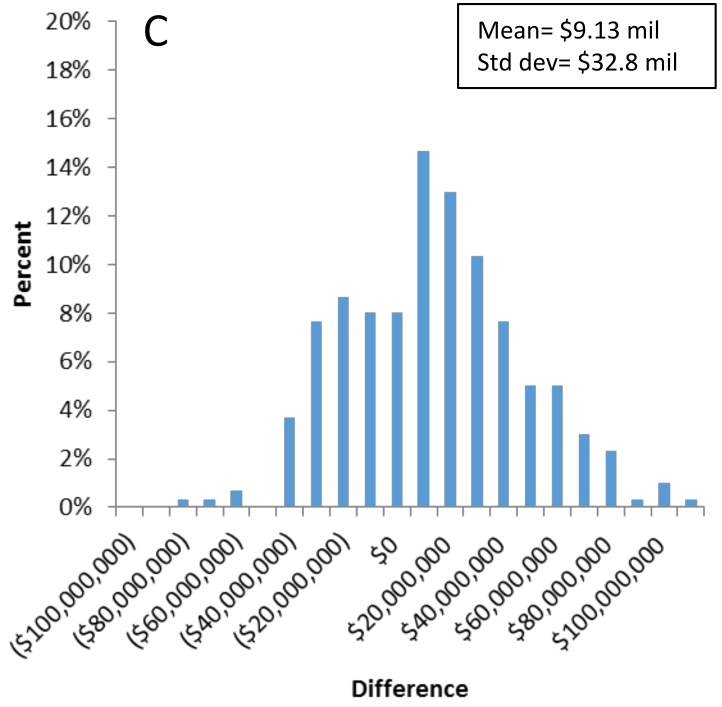
Results – Fixed beach, varying channel



65% chance difference > $0



61% chance difference > $0



63% chance difference > $0

> $0 indicates Alt B costs less than Alt U

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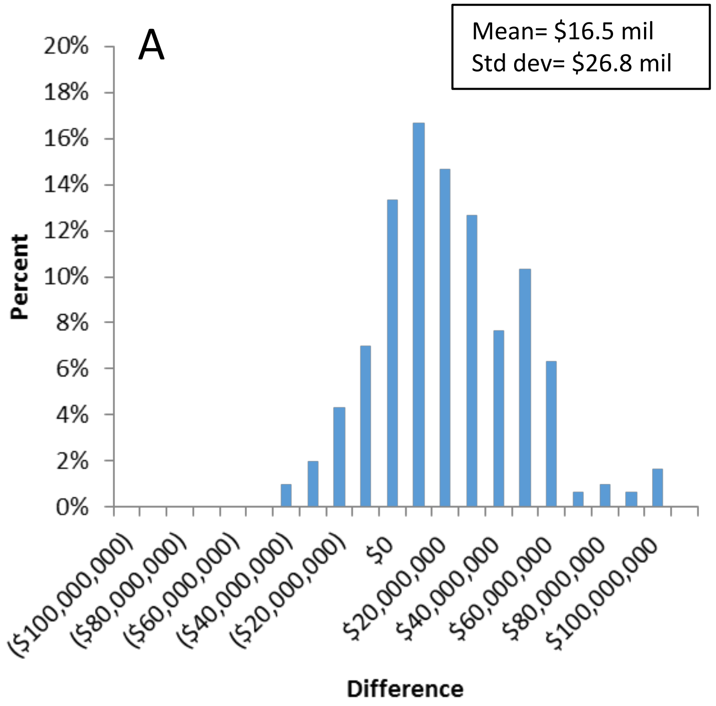
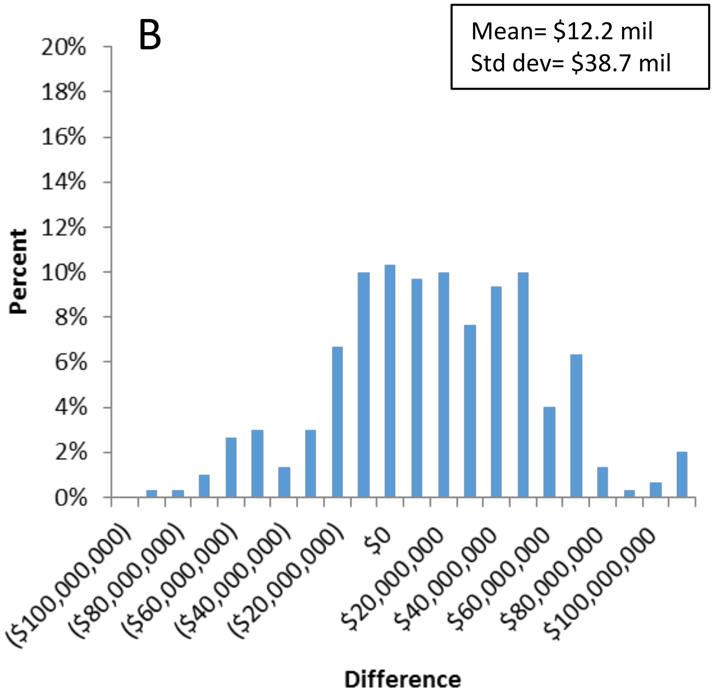
Results – Varying beach, fixed channel

- 300, 50-yr period simulations
- Beach width = 100 ft
- Beach length varies
  - (A) L = 1 mile
  - (B) L = 2 miles
  - (C) L = 3 miles
- Inlet channel depths and widths fixed
  - Depth = 20 ft
  - Width = 200 ft

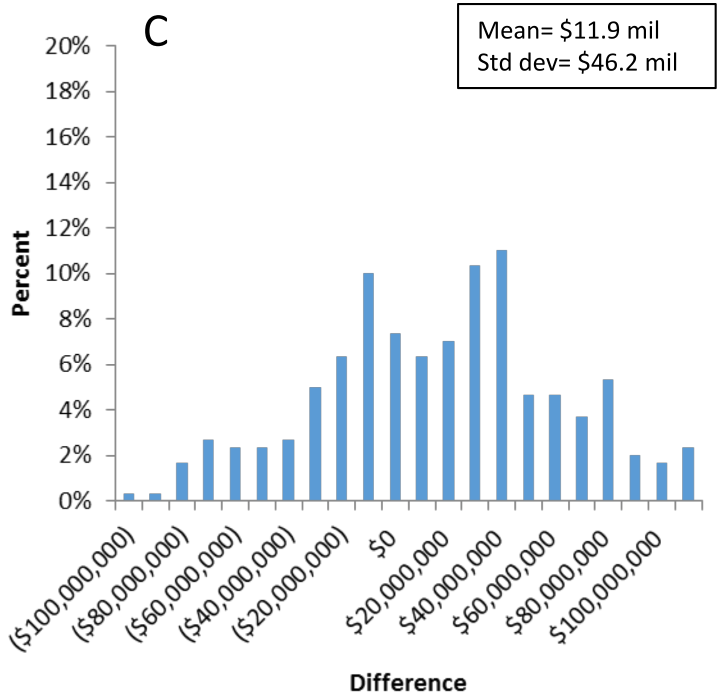
Results – Varying beach, fixed channel



72% chance difference > $0



61% chance difference > $0

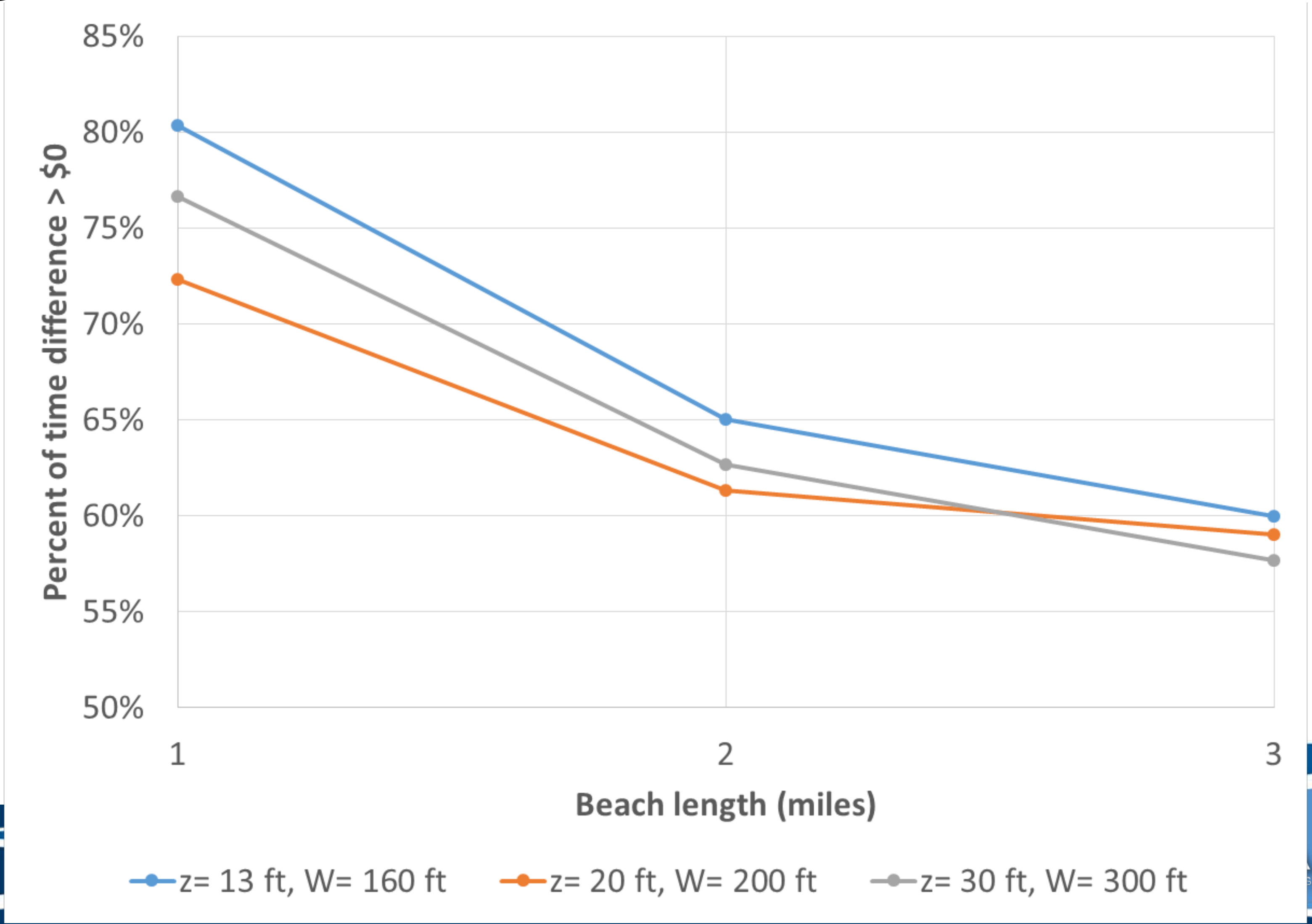


59% chance difference > $0

> $0 indicates Alt B costs less than Alt U

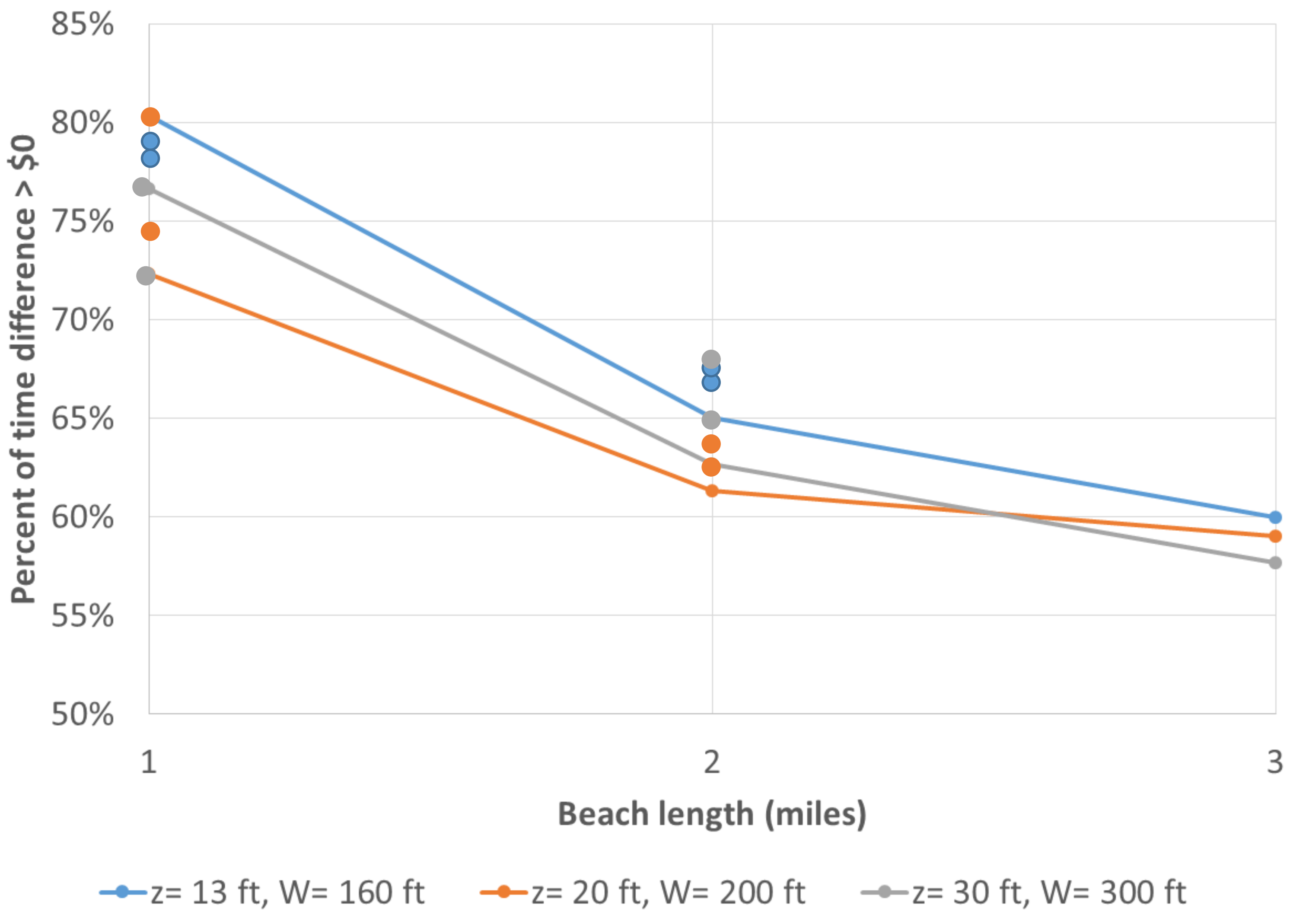
Results – Varying beach and channel

- 50-yr cost difference between Alternative B and Alternative U
- Beach width fixed (100 ft)

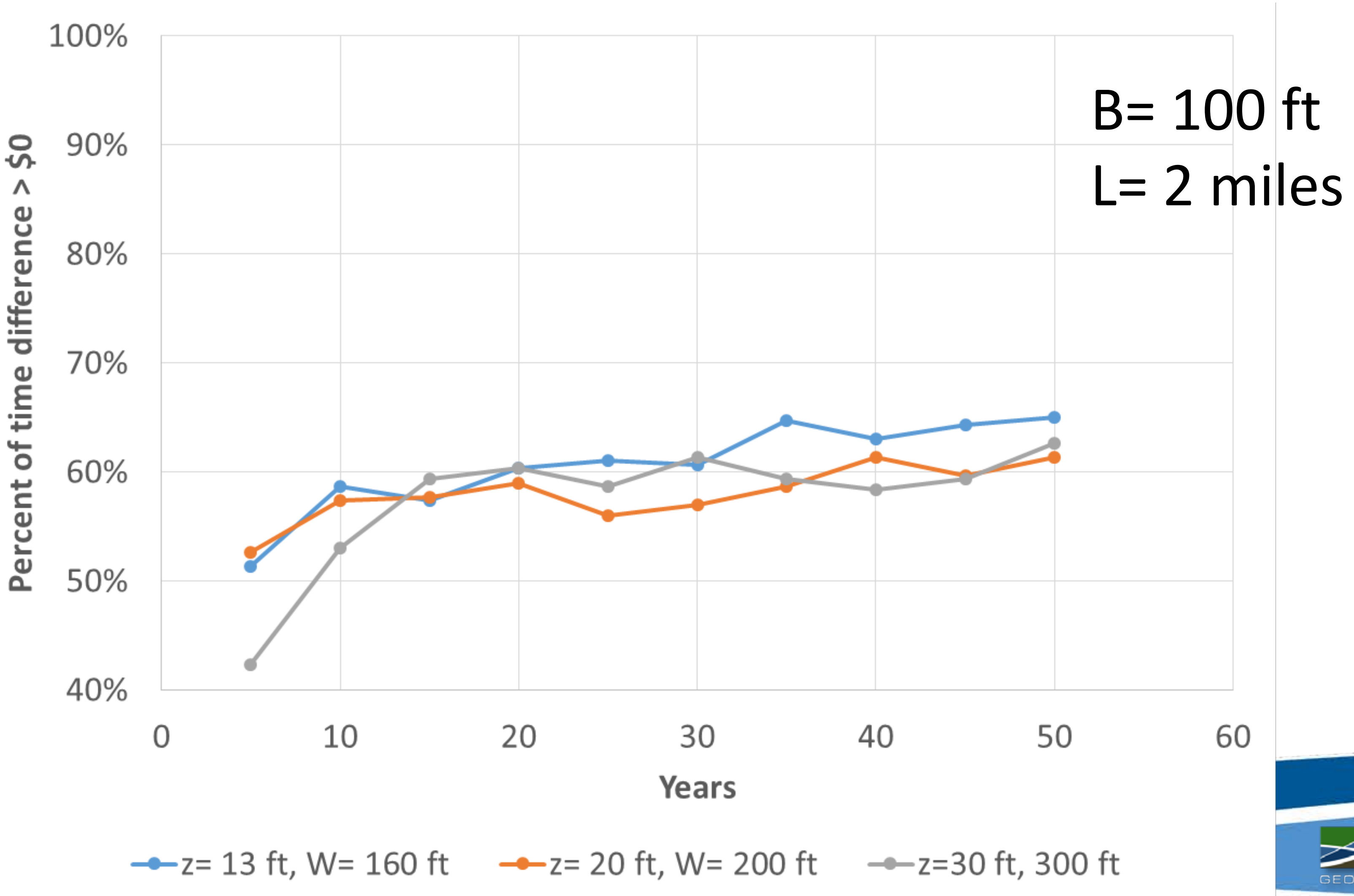


Results – Varying beach and channel

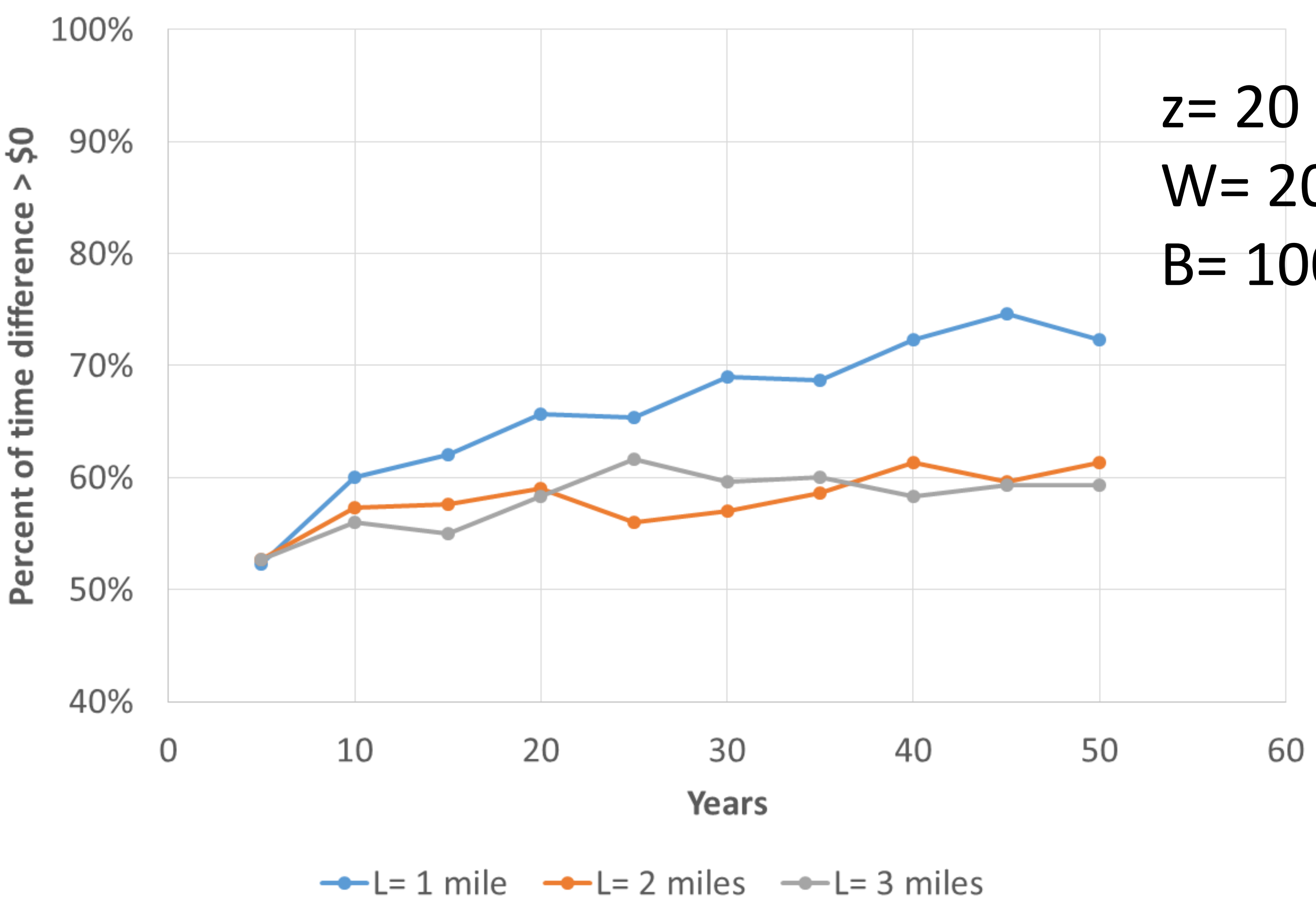
- 50-yr cost difference between Alternative B and Alternative U
- Beach width fixed (50, 100 [lines], 150 ft)



Results – Different time periods



Results – Different time periods



z= 20 ft

W= 200 ft

B= 100 ft

Conclusions

- Shorter beach project lengths have greater chance of saving money by employing RSM practices
  - Shorter beach fills require less sand to fill beach template than longer fills
  - Therefore, placement of dredged channel material on beach could delay need for filling beach template with offshore sand
- Longer beach projects have less chance (but ~60% chance) of saving money by employing RSM practices
- Channel dimensions play a small role in cost effectiveness of RSM practices
- In it for the long haul (at least 10 yrs to improve chances)

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Conclusions

- Because alternatives' cost differences are close, other issues (with offshore source or upland disposal) may tip the scale toward placing dredged material on beach
- ***<u>While based on many gross assumptions, this probabilistic approach might provide a framework for which to evaluate and make case for regional sediment management practices</u>***

Probabilistic Alternatives Analysis of Regional Sediment Management Practices

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