aws
Australian
Water School

100th webinar

WELCOME TO OUR 100TH!

Karen Rouse | CEO | Water Research Australia

The AWS professional development offerings expanded to webinars in June 2016, and since its inception we've continued to provide learning and discussion opportunities.

25,000+
participants
from science, engineering, technical, planning, policy, environment, agriculture, mining, asset management and manufacturing.

142 expert
presenters
have shared their expertise and knowledge across a wide range of areas relevant to the water sector

160,000+
views
and counting of our webinars, meaning our knowledge is creating impact well into the future

168
countries
have tuned in to hear about the latest developments in water science and technology

45
courses
have been developed based on our webinars and the needs of our participants

OUR 100TH AND BEYOND!

Karen Rouse | CEO | Water Research Australia

- Working with new organisations and experts to deliver the best in online training and education through webinars, live and on-demand courses

- More hands-on courses based on pressing needs and tech advancements including python scripting, climate adaptation, and modelling

- Continued commitment to provision of the latest knowledge on the surface water and groundwater modelling packages, including HEC-RAS, MODFLOW, QGIS, HEC-HMS and TUFLOW.

aws Australian Water School | 100th webinar

WEBINAR

Rocking it!

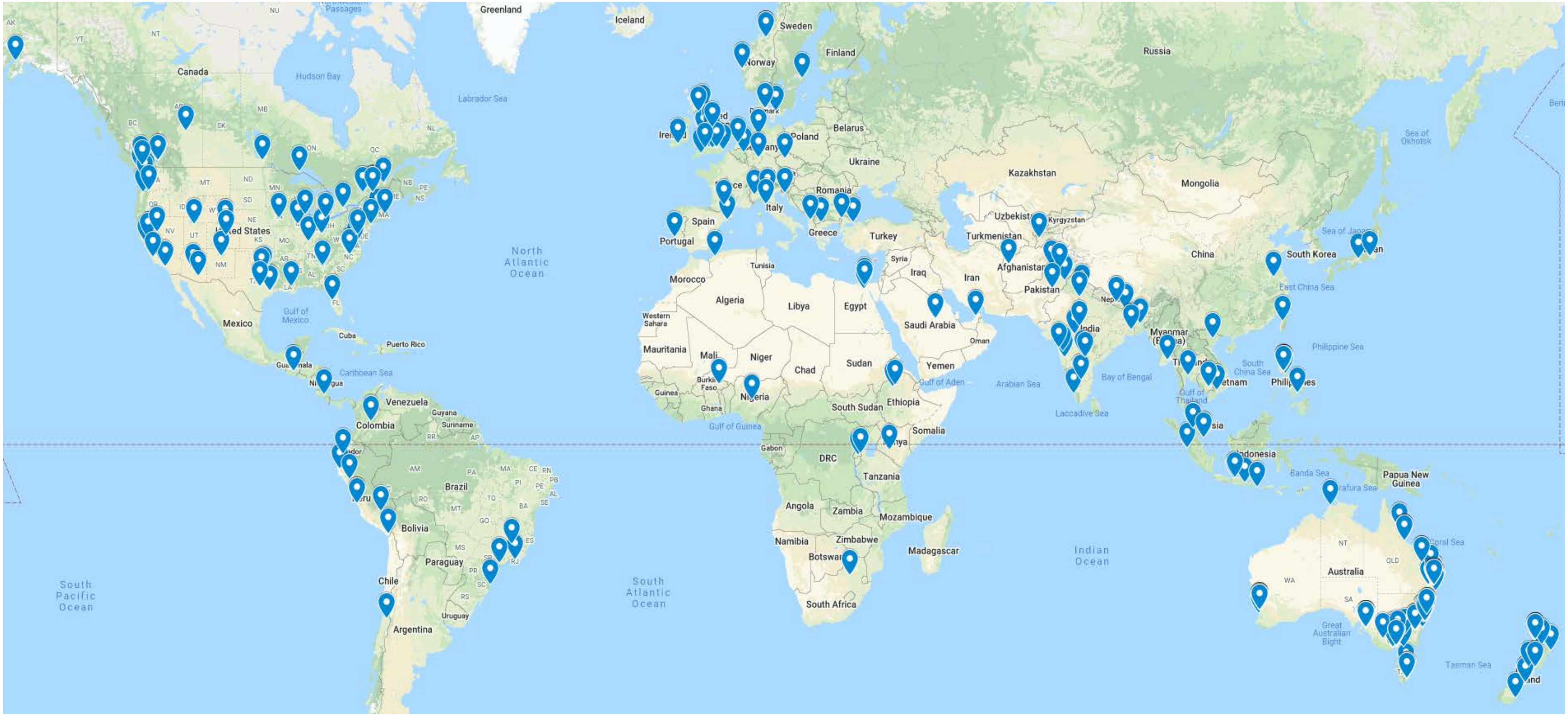
Using hydraulic modelling results for rock sizing

Casey Kramer
Natural Waters

NATURAL WATERS

WELCOME ATTENDEES

aws Australian Water School | 100th webinar



Casey Kramer | Natural Waters

Casey is a recognized expert in the fields of hydrology, hydraulics, scour, river engineering, sediment transport and fish passage, while specializing in the hydraulic design of transportation facilities. He has been involved with over 400 water and transportation projects.

NATURAL WATERS

Casey is well recognized for his collaborative approach involving interdisciplinary teams of water resources and infrastructure specialists to develop environmentally beneficial solutions for critical infrastructure, flood control, stormwater, erosion control, channel stabilization, and environmental restoration projects.

COMING UP

ON-DEMAND COURSES

1D HEC-RAS
water modelling

2D HEC-RAS
water modelling

MODFLOW
groundwater modelling

HEC-RAS Structures
water modelling

QGIS
water modelling

WEBINARS

2020

16 Dec — **2D and 3D Modelling** for sediment transport

2021

17 Feb — **Rain-on-Grid Modelling** is it accurate?

LIVE TRAINING

2021
Live Course Calendar launching soon!

AWS Free Webinar: 2 December 2020

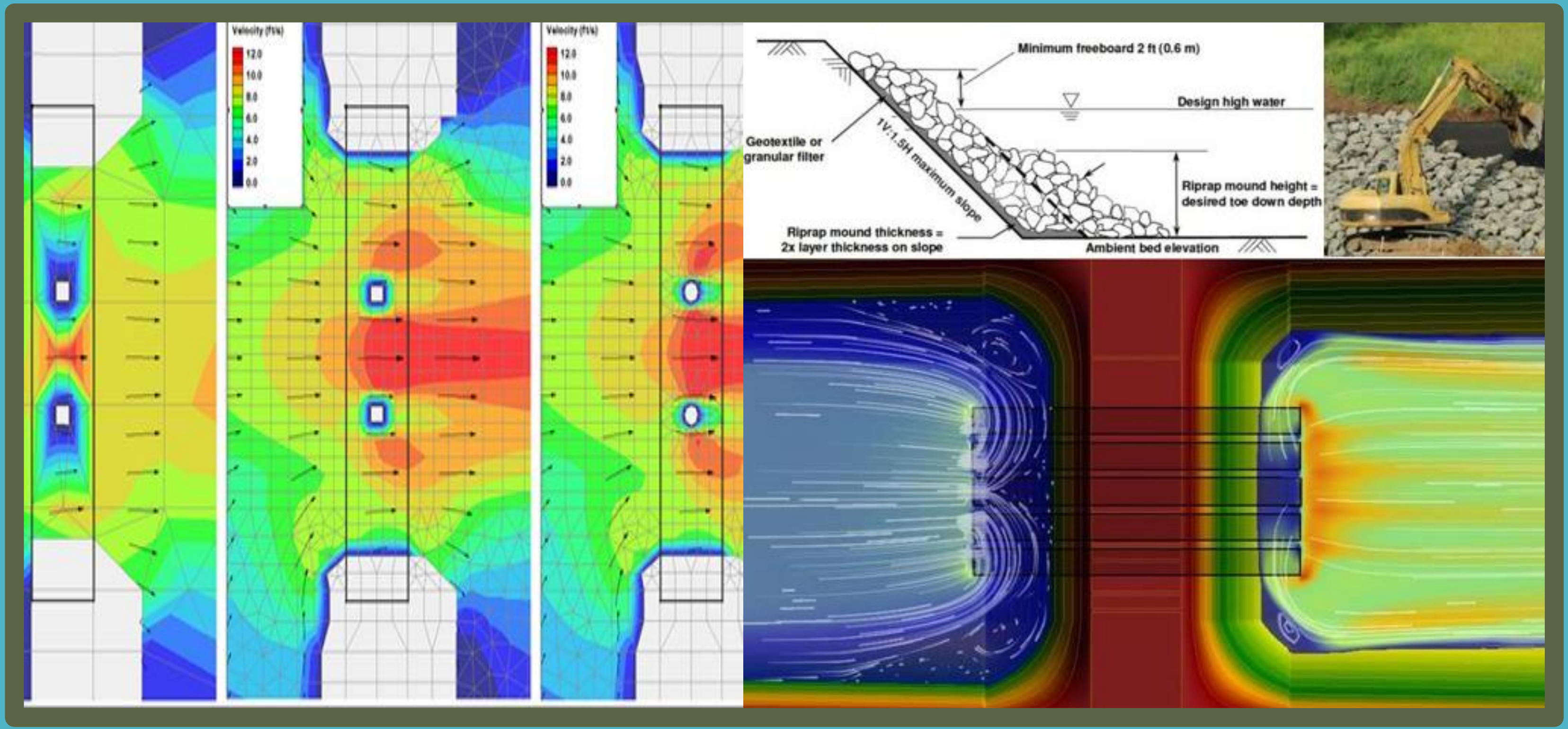
Presented by:

Casey Kramer
Natural Waters

Krey Price
Surface
Water Solutions

Rocking It!

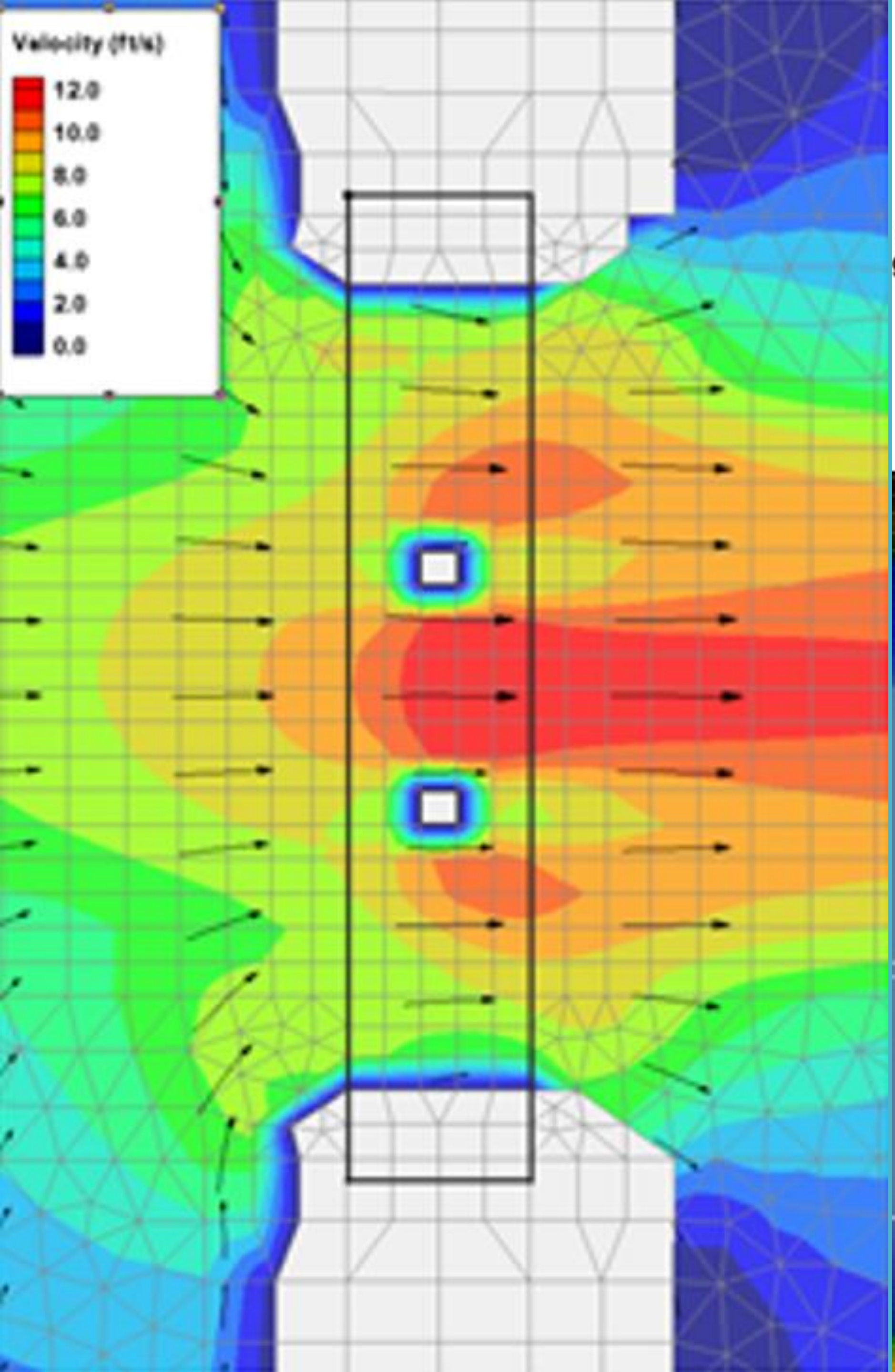
Using hydraulic modelling results for rock sizing

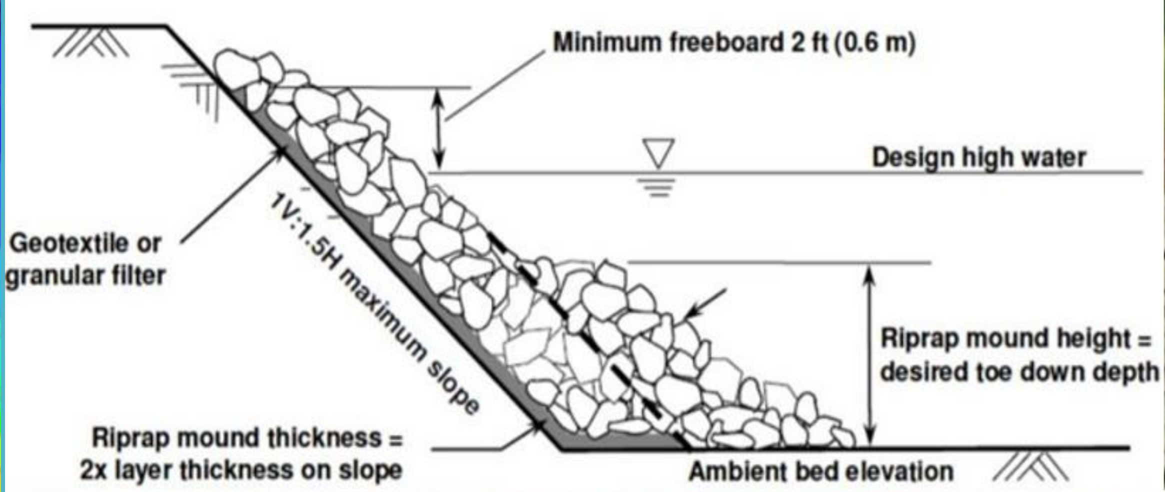


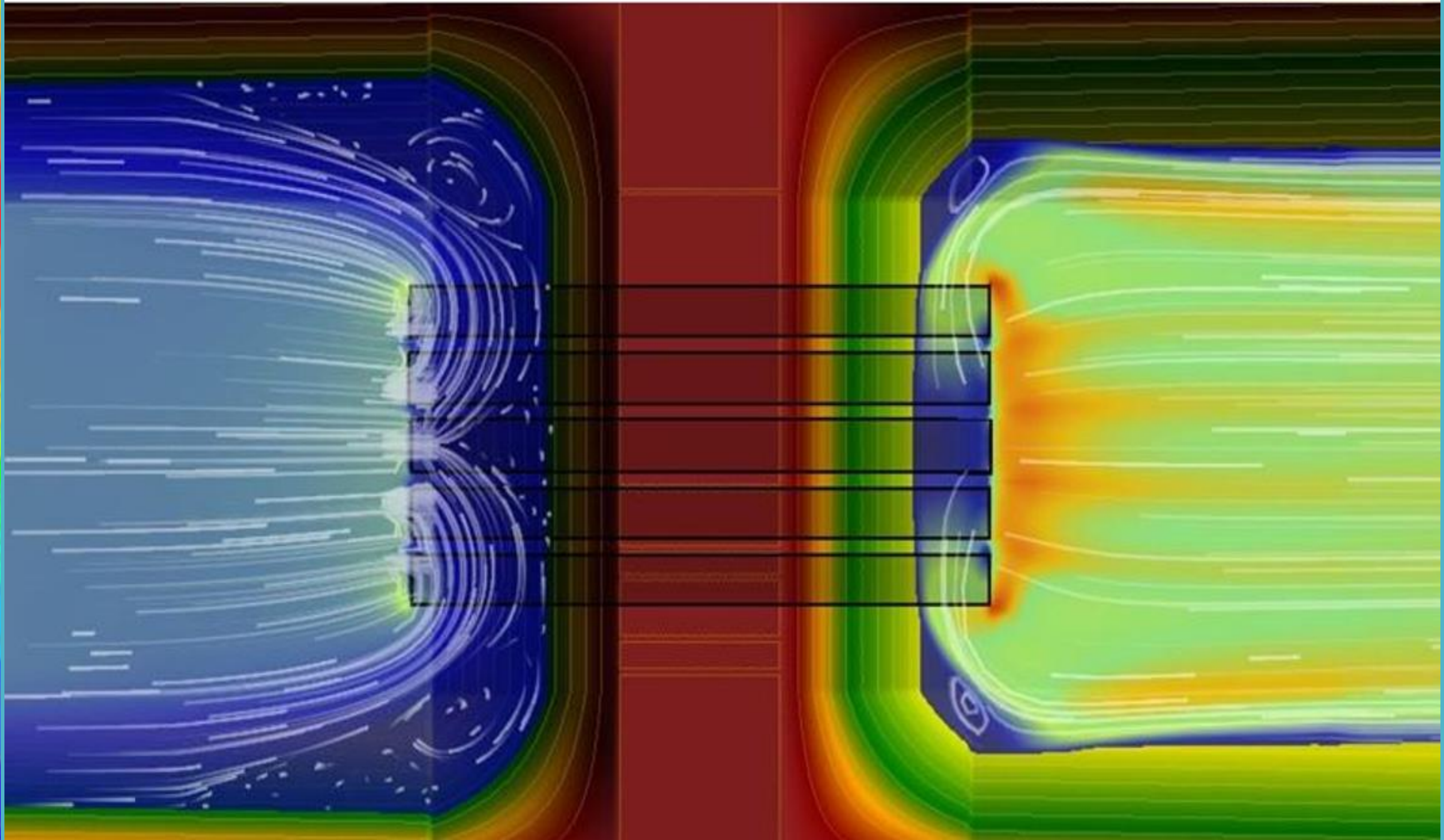
Australian Water School

Brisbane River Flood 2011

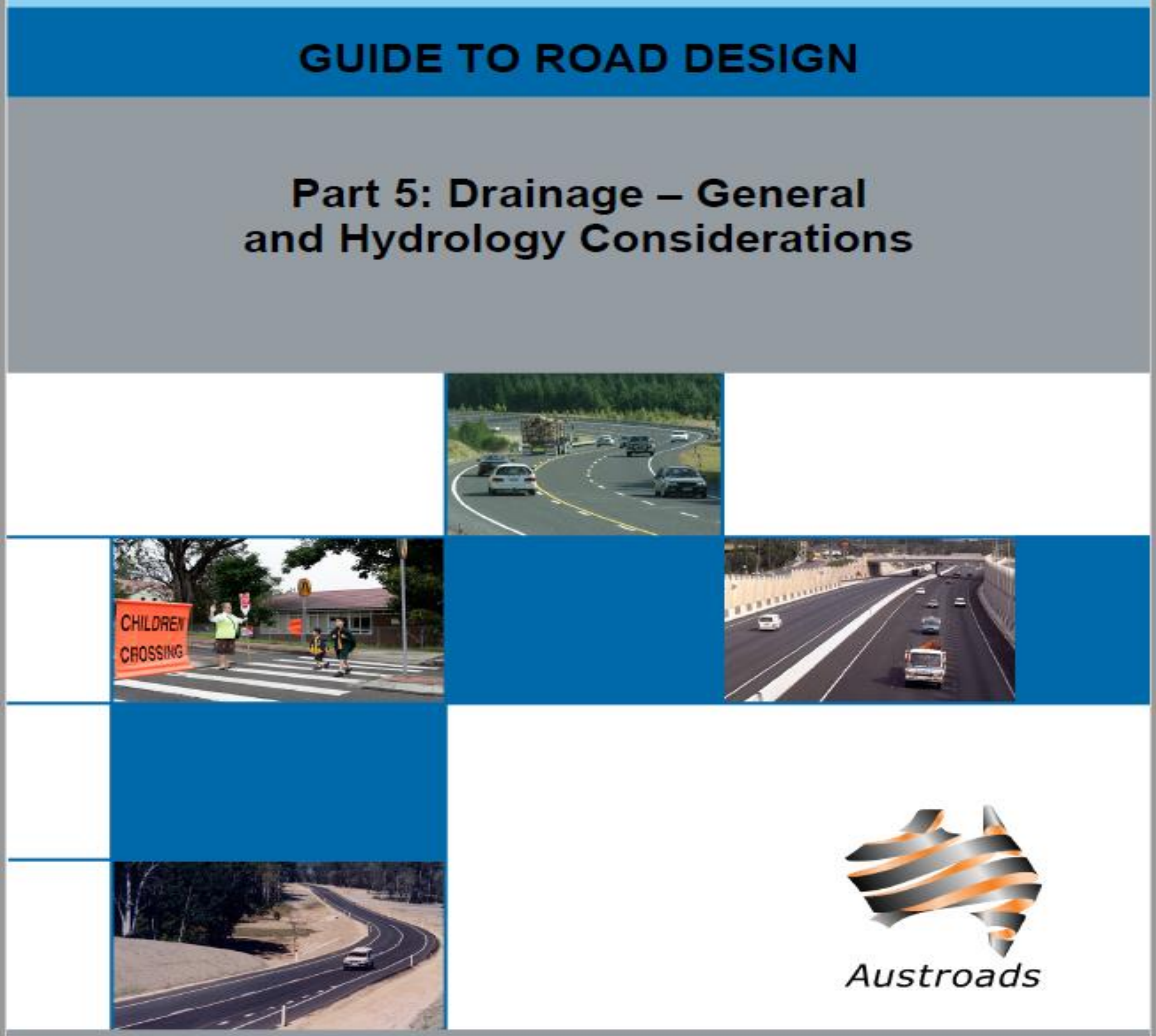
Bedrock Erosion With Bridge Failure (Tou-Chien River, Taiwan, Chung-Ta Liao 2014)

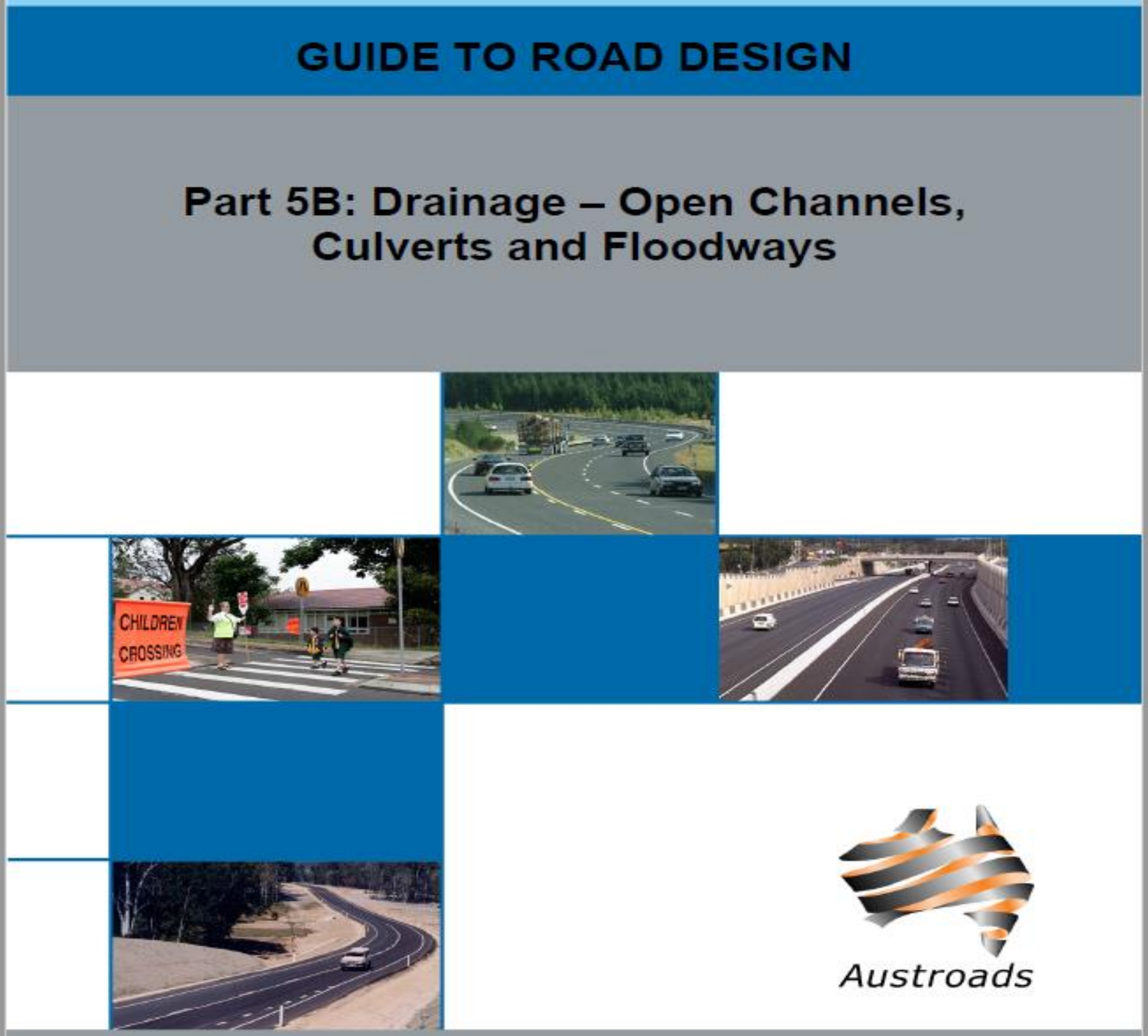

Velocity (ft/s)
12.0
10.0
8.0
6.0
4.0
2.0
0.0


Minimum freeboard 2 ft (0.6 m)
Design high water
Geotextile or granular filter
1V:1.5H maximum slope
Riprap mound height = desired toe down depth
Riprap mound thickness = 2x layer thickness on slope
Ambient bed elevation

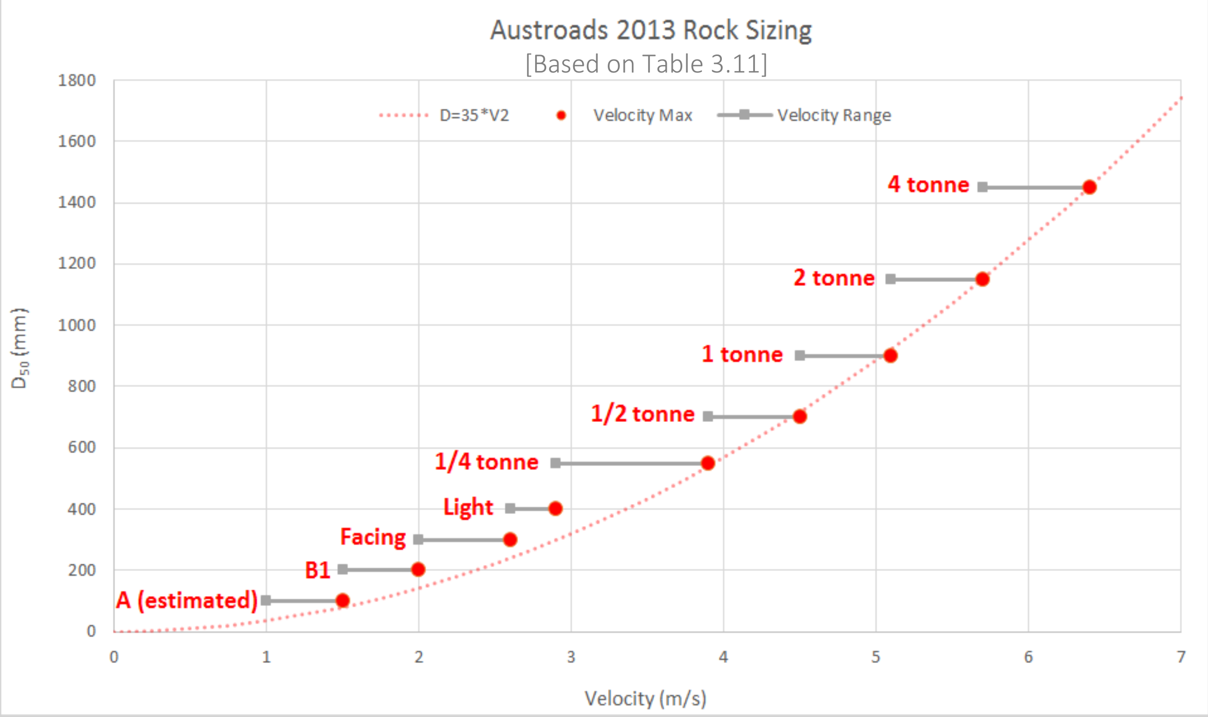


Austroads 2013

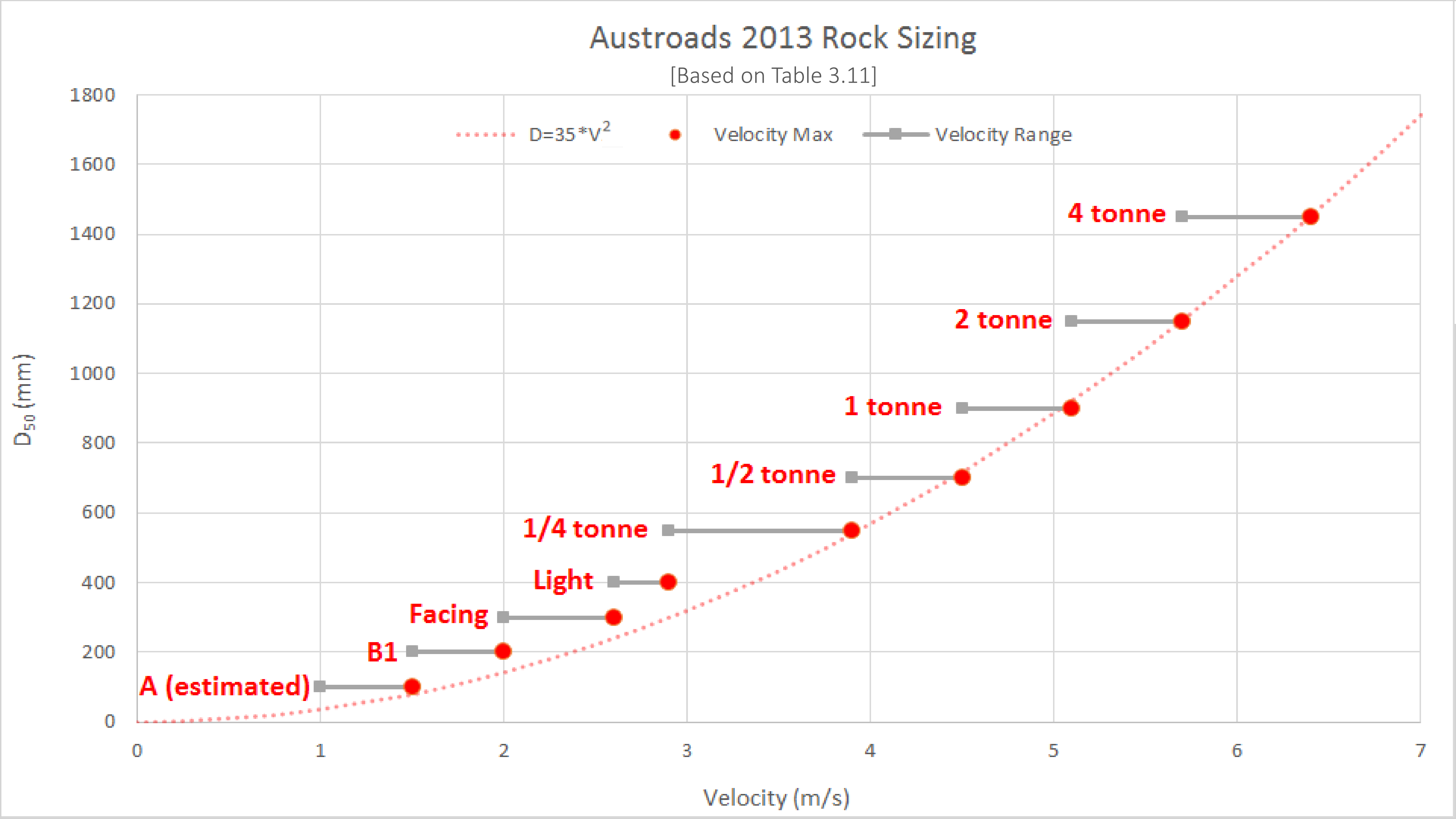




Velocity (m/s)	Class of rock protection (tonne)	Section thickness, *T* (m)
< 2	None	–
2.0–2.6	Facing	0.50
2.6–2.9	Light	0.75
2.9–3.9	¼	1.00
3.9–4.5	½	1.25
4.5–5.1	1.0	1.60
5.1–5.7	2.0	2.00
5.7–6.4	4.0	2.50
> 6.4	Special	–



Rock class	Rock size[1] (m)	Rock mass (kg)	Minimum percentage of rock larger than
Facing	0.40	100	0
	0.30	35	50
	0.15	2.5	90
Light	0.55	250	0
	0.40	100	50
	0.20	10	90
¼ tonne	0.75	500	0
	0.55	250	50
	0.30	35	90
½ tonne	0.90	1000	0
	0.70	450	50
	0.40	100	90
1 tonne	1.15	2000	0
	~~0.60~~	1000	50
	0.55	250	90
2 tonne	1.45	4000	0
	1.15	2000	50
	0.75	500	90
4 tonne	1.80	8000	0
	1.45	4000	50
	0.90	100	90



Austroads 2013 Rock Sizing
[Based on Table 3.11]
D=35*V2
Velocity Max
Velocity Range
4 tonne
2 tonne
1 tonne
1/2 tonne
1/4 tonne
Light
Facing
B1
A (estimated)
1800
1600
1400
1200
1000
800
600
400
200
0
0
1
2
3
4
5
6
7
D50 (mm)
Velocity (m/s)

Austroads 2013?

Austroads 2013

↑

MRWA 2006

↑

Austroads 1994

↑

CABS 1970

↑

CABS 1960

↑

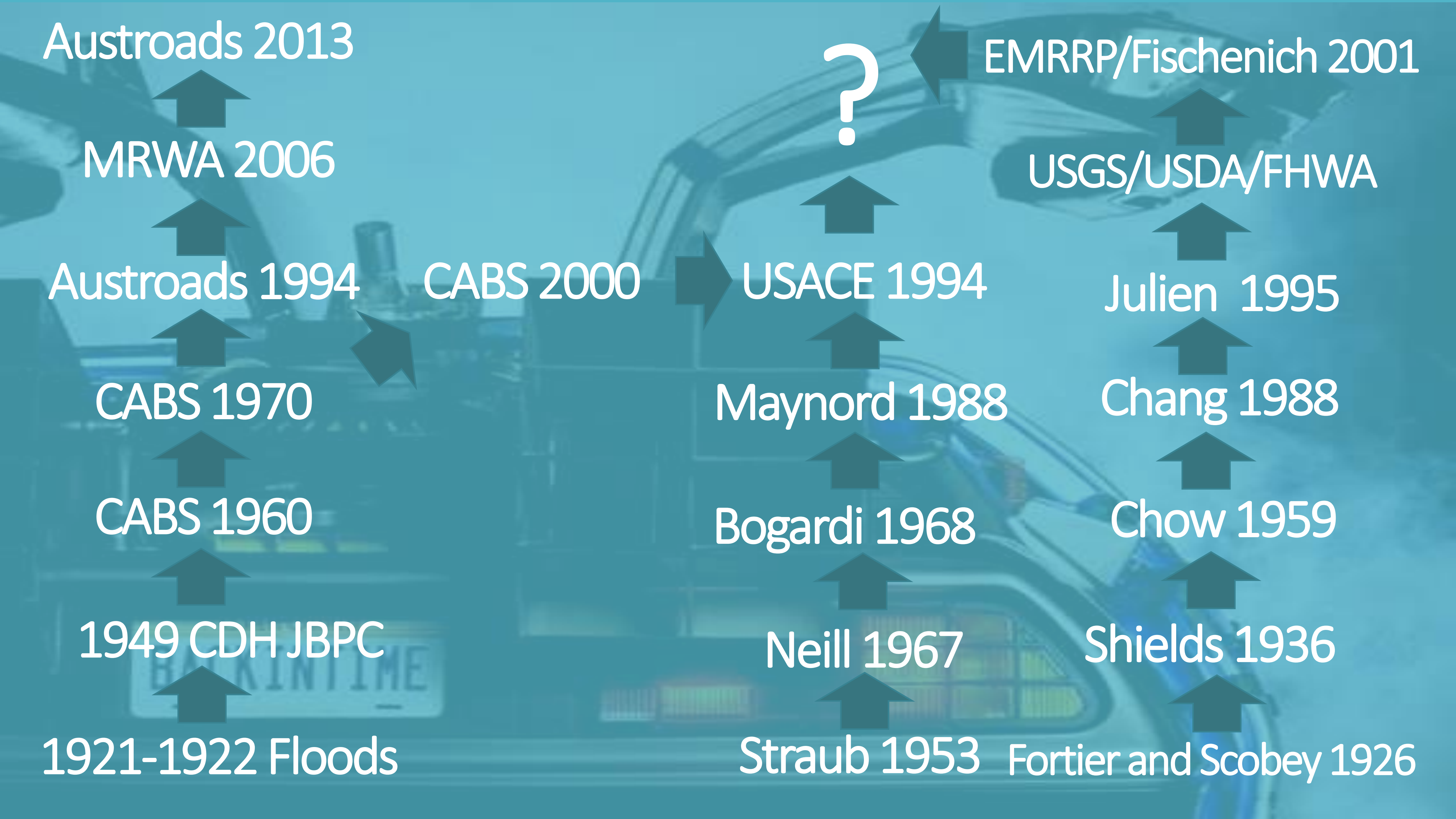
1949 CDH JBPC

↑

1921-1922 Floods


Austroads 2013
MRWA 2006
Austroads 1994
CABS 1970
CABS 1960
1949 CDH JBPC
1921-1922 Floods
EMRRP/Fischenich 2001
USGS/USDA/FHWA
Julien 1995
Chang 1988
Chow 1959
Shields 1936
Fortier and Scobey 1926


Austroads 2013
MRWA 2006
Austroads 1994
CABS 1970
CABS 1960
1949 CDH JBPC
1921-1922 Floods
CABS 2000
USACE 1994
Maynord 1988
Bogardi 1968
Neill 1967
Straub 1953
EMRRP/Fischenich 2001
USGS/USDA/FHWA
Julien 1995
Chang 1988
Chow 1959
Shields 1936
Fortier and Scobey 1926



Austroads 2013
MRWA 2006
Austroads 1994
CABS 1970
CABS 1960
1949 CDH JBPC
1921-1922 Floods
CABS 2000
?
USACE 1994
Maynord 1988
Bogardi 1968
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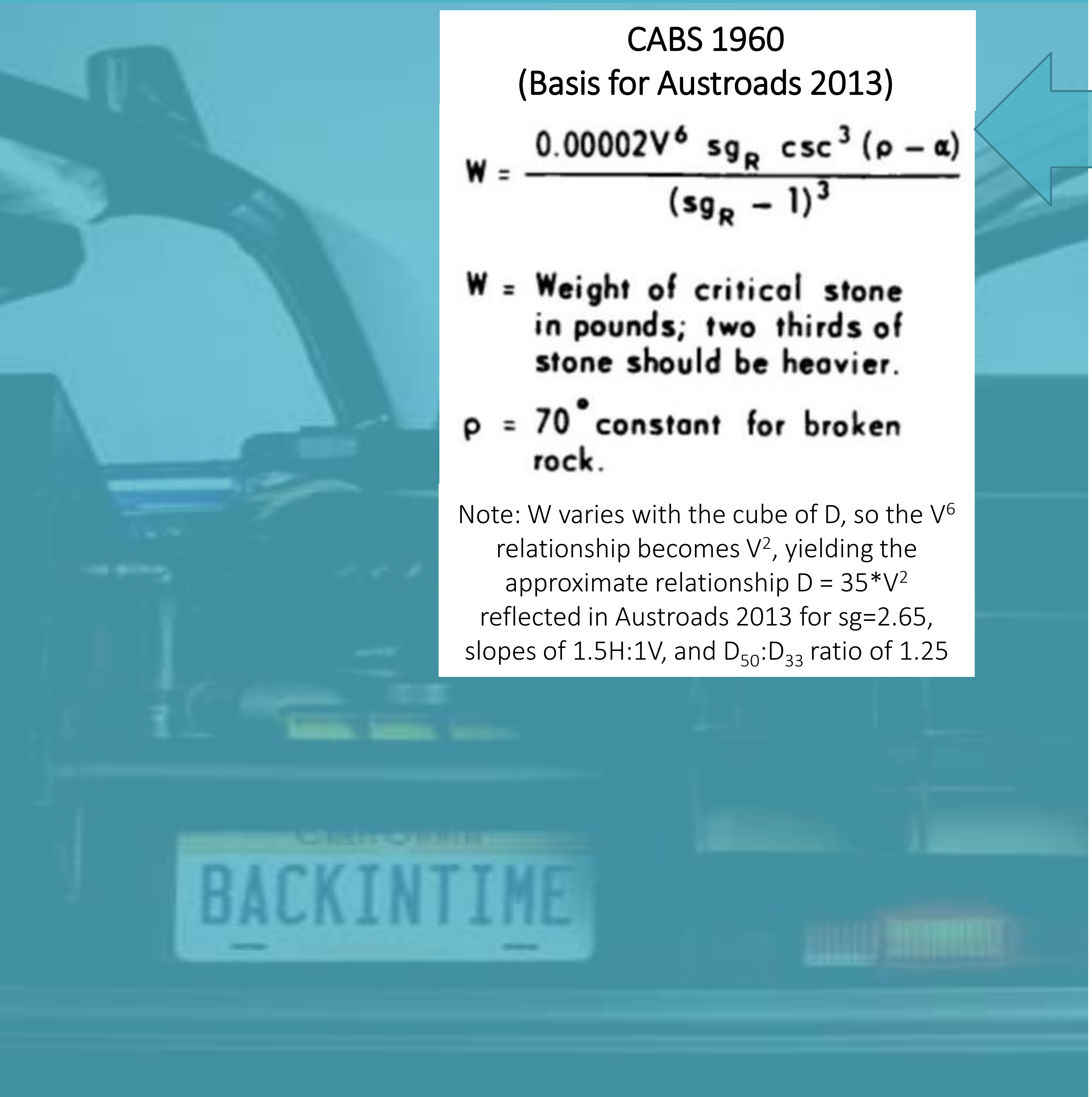
Austroads 2013
MRWA 2006
Austroads 1994
CABS 1970
CABS 1960
1949 CDH JBPC
1921-1922 Floods
CABS 2000
Casey's Presentation
USACE 1994
Maynord 1988
Bogardi 1968
Neill 1967
Straub 1953
EMRRP/Fischenich 2001
USGS/USDA/FHWA
Julien 1995
Chang 1988
Chow 1959
Shields 1936
Fortier and Scobey 1926



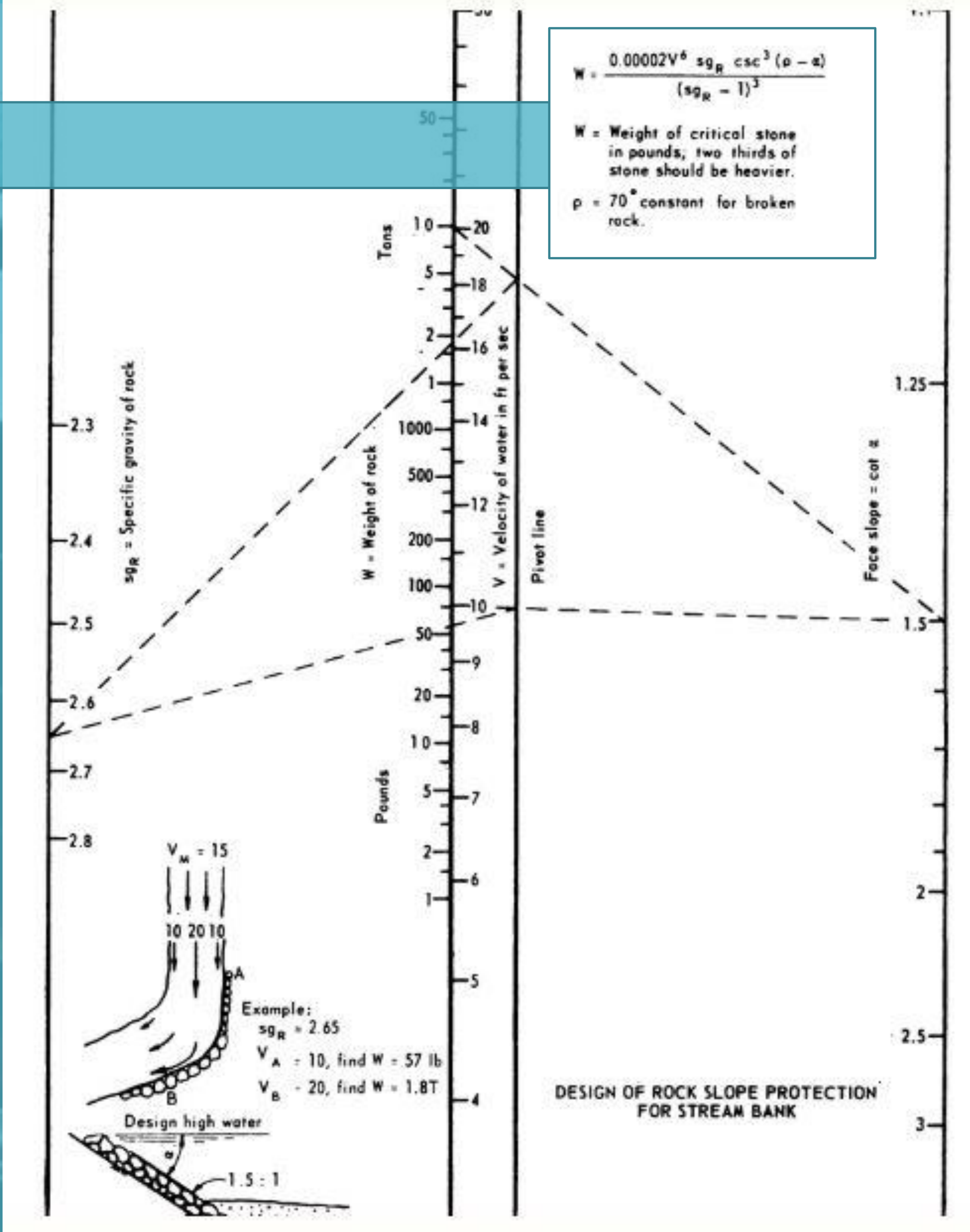
CABS 1960
(Basis for Austroads 2013)

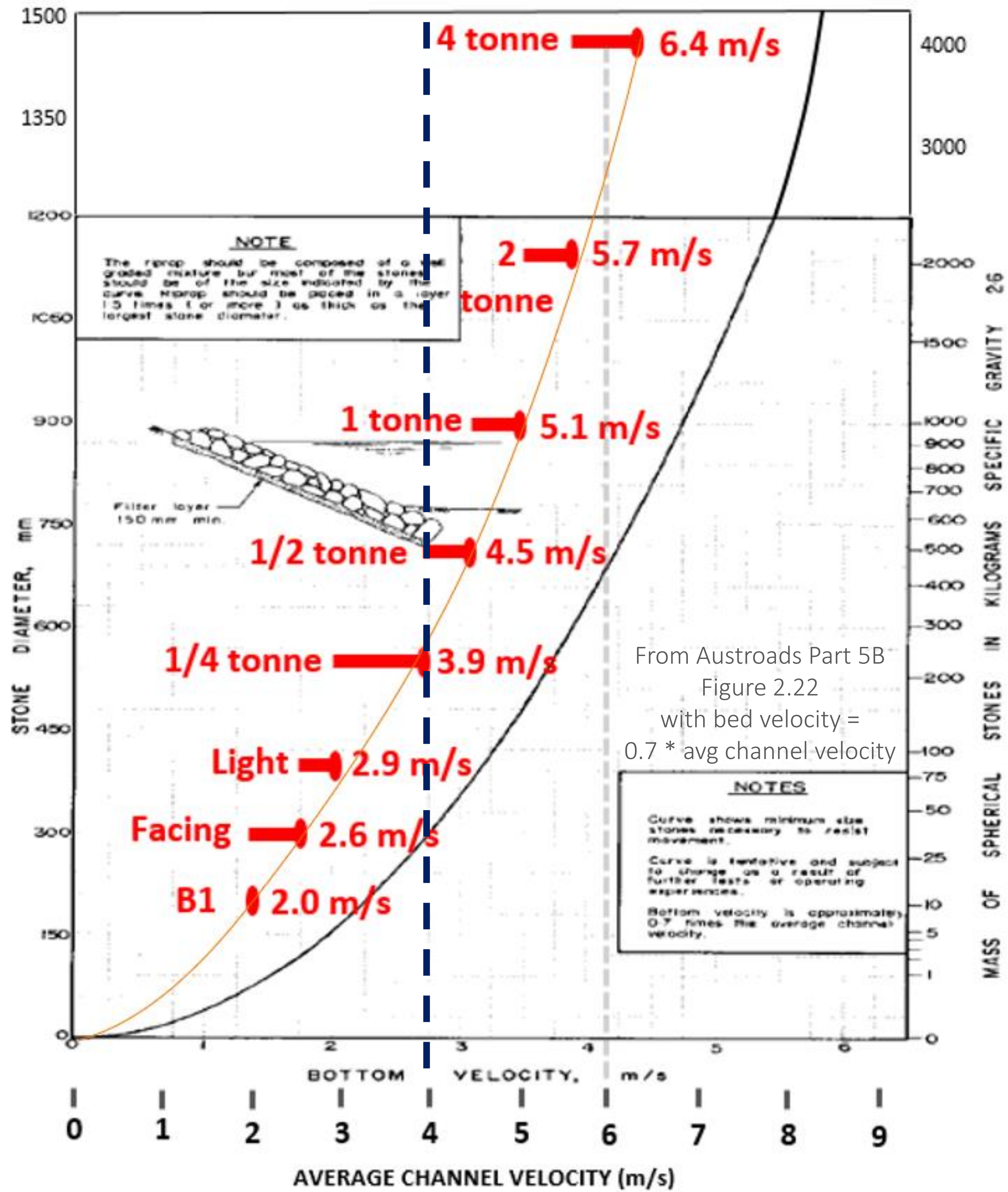
$$W = \frac{0.00002V^6 \; sg_R \; \csc^3(\rho - \alpha)}{(sg_R - 1)^3}$$

W = Weight of critical stone in pounds; two thirds of stone should be heavier.

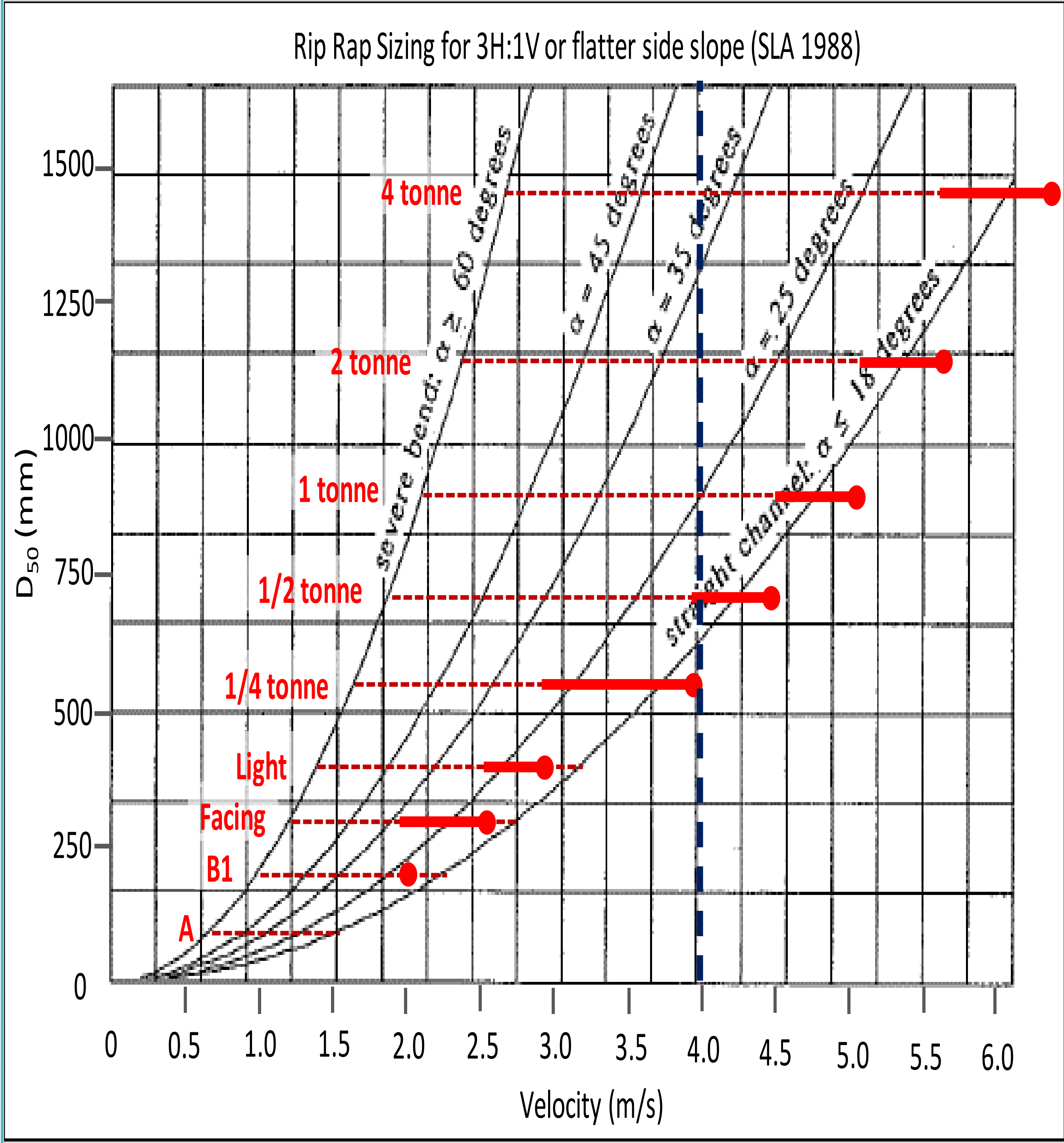
ρ = 70° constant for broken rock.

Note: W varies with the cube of D, so the V^6 relationship becomes V^2, yielding the approximate relationship D = 35*V^2 reflected in Austroads 2013 for sg=2.65, slopes of 1.5H:1V, and D_{50}:D_{33} ratio of 1.25





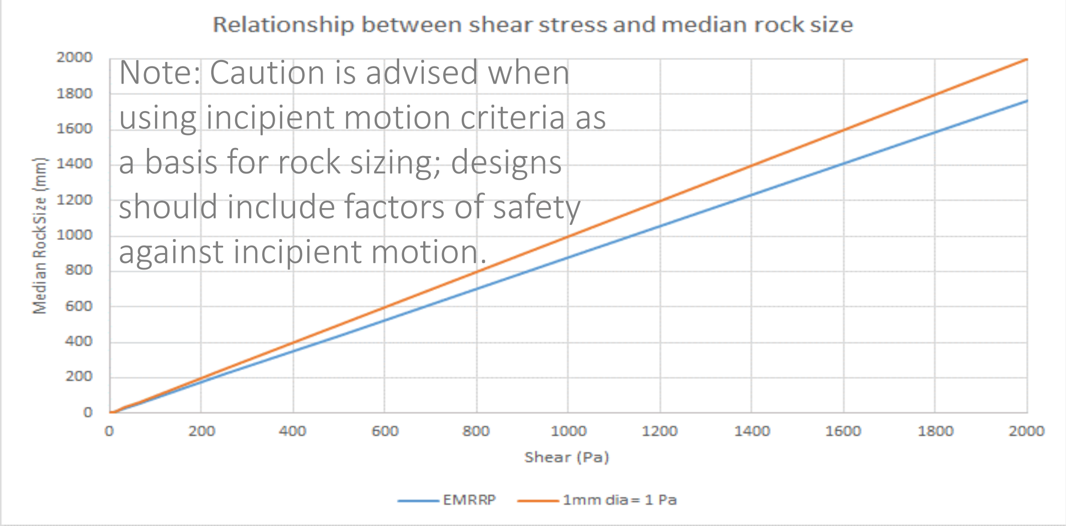
4 tonne
6.4 m/s
2 tonne
5.7 m/s
1 tonne
5.1 m/s
1/2 tonne
4.5 m/s
1/4 tonne
3.9 m/s
Light
2.9 m/s
Facing
2.6 m/s
B1
2.0 m/s
NOTE
The riprap should be composed of a well graded mixture but most of the stones should be of the size indicated by the curve. Riprap should be placed in a layer 1.5 times (or more) as thick as the largest stone diameter.
Filter layer 150 mm min.
From Austroads Part 5B
Figure 2.22
with bed velocity =
0.7 * avg channel velocity
NOTES
Curve shows minimum size stones necessary to resist movement.
Curve is tentative and subject to change as a result of further tests or operating experiences.
Bottom velocity is approximately 0.7 times the average channel velocity.
STONE DIAMETER, mm
BOTTOM VELOCITY, m/s
MASS OF SPHERICAL STONES IN KILOGRAMS SPECIFIC GRAVITY 2.6
AVERAGE CHANNEL VELOCITY (m/s)

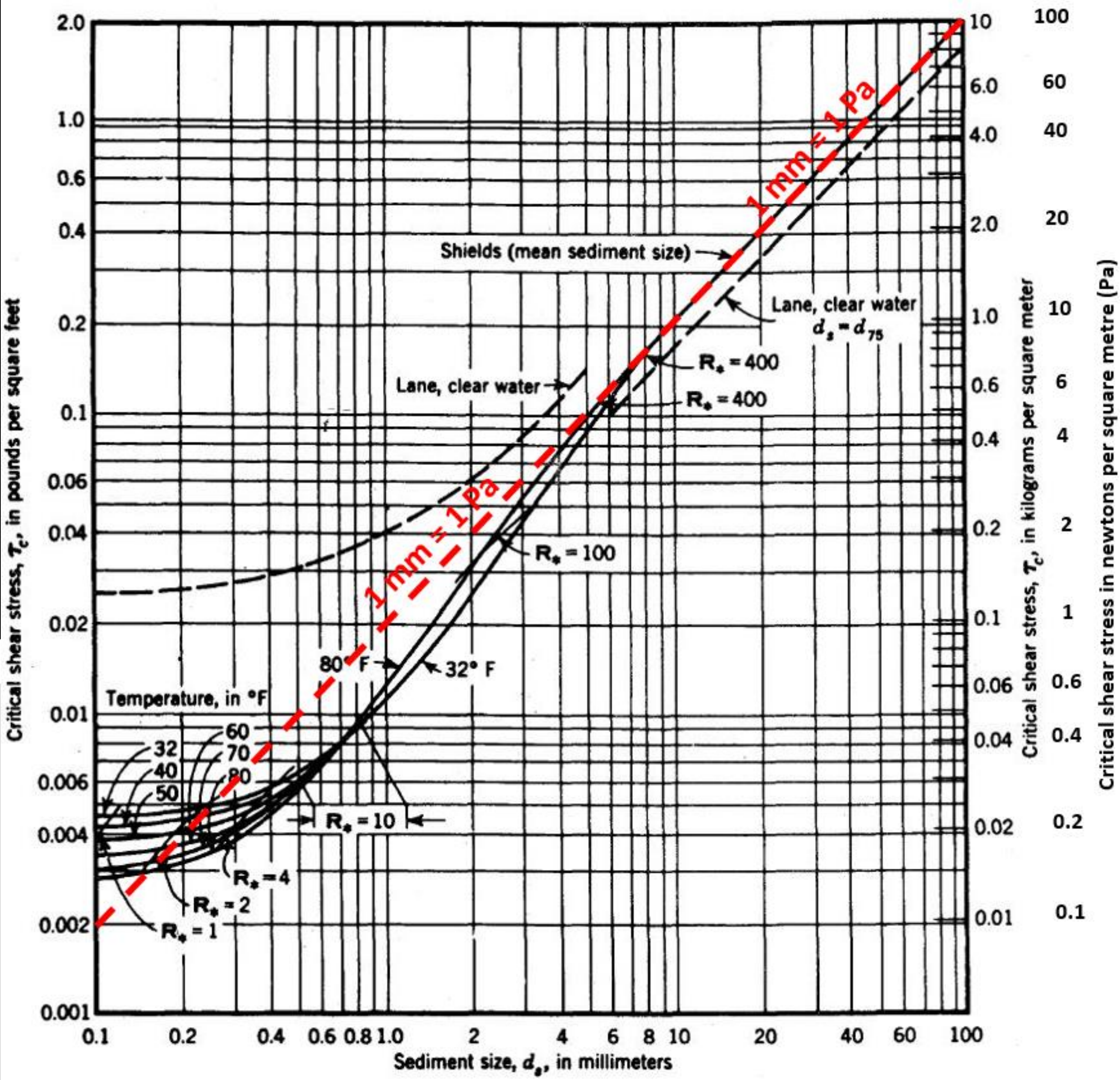


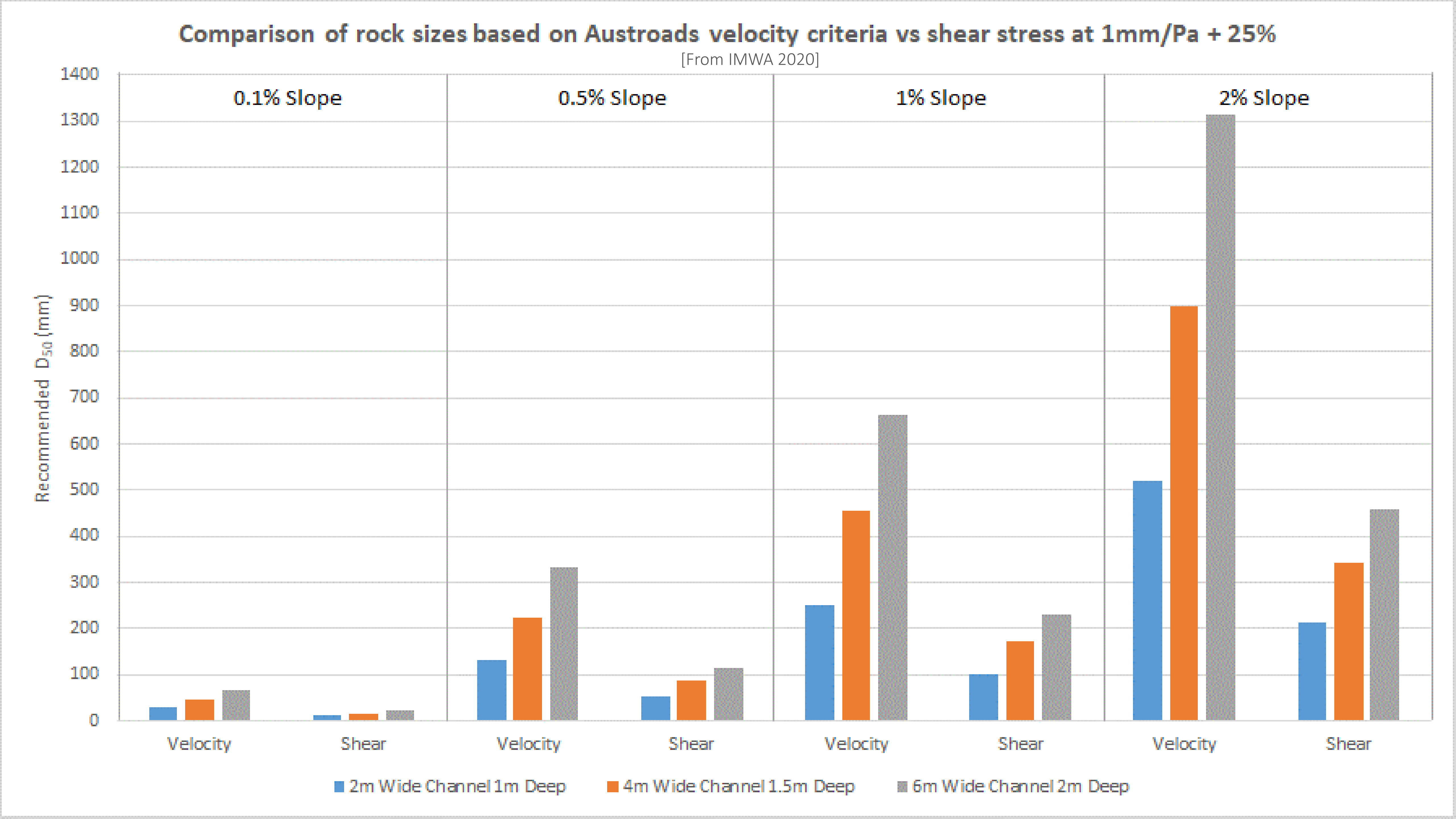
Rip Rap Sizing for 3H:1V or flatter side slope (SLA 1988)
4 tonne
2 tonne
1 tonne
1/2 tonne
1/4 tonne
Light
Facing
B1
A
severe bend: α ≥ 60 degrees
α = 45 degrees
α = 35 degrees
α = 25 degrees
straight channel: α ≤ 15 degrees
D50 (mm)
Velocity (m/s)

Rock class	Particle diameter	Angle of repose	Critical shear stress	Critical shear velocity	Particle diameter	Critical shear stress	Critical shear velocity
Class name	*d_s (in)*	*ϕ (deg)*	*τ_{cr} (lb/sf)*	*V_{*c} (ft/s)*	(mm)	(Pa)	(m/s)
Boulder							
Very large	>80	42	37.4	4.36	2032	1791	1.33
Large	>40	42	18.7	3.08	1016	896	0.94
Medium	>20	42	9.3	2.20	508	445	0.67
Small	>10	42	4.7	1.54	254	225	0.47
Cobble							
Large	>5	42	2.3	1.08	127	110	0.33
Small	>2.5	41	1.1	0.75	64	53	0.23
Gravel							
Very coarse	>1.3	40	0.54	0.52	33	26	0.16
Coarse	>0.6	38	0.25	0.36	15	12	0.11
Medium	>0.3	36	0.12	0.24	8	6	0.07
Fine	>0.16	35	0.06	0.17	4	3	0.05
Very fine	>0.08	33	0.03	0.12	2	1	0.04
Sands							
Very coarse	>0.04	32	0.01	0.070	1.0	0.5	0.021
Coarse	>0.02	31	0.006	0.055	0.5	0.3	0.017
Medium	>0.01	30	0.004	0.045	0.3	0.2	0.014
Fine	>0.005	30	0.003	0.040	0.13	0.1	0.012
Very fine	>0.003	30	0.002	0.035	0.08	0.1	0.011
Silts							
Coarse	>0.002	30	0.001	0.030	0.05	0.05	0.009
Medium	>0.001	30	0.001	0.025	0.03	0.05	0.008

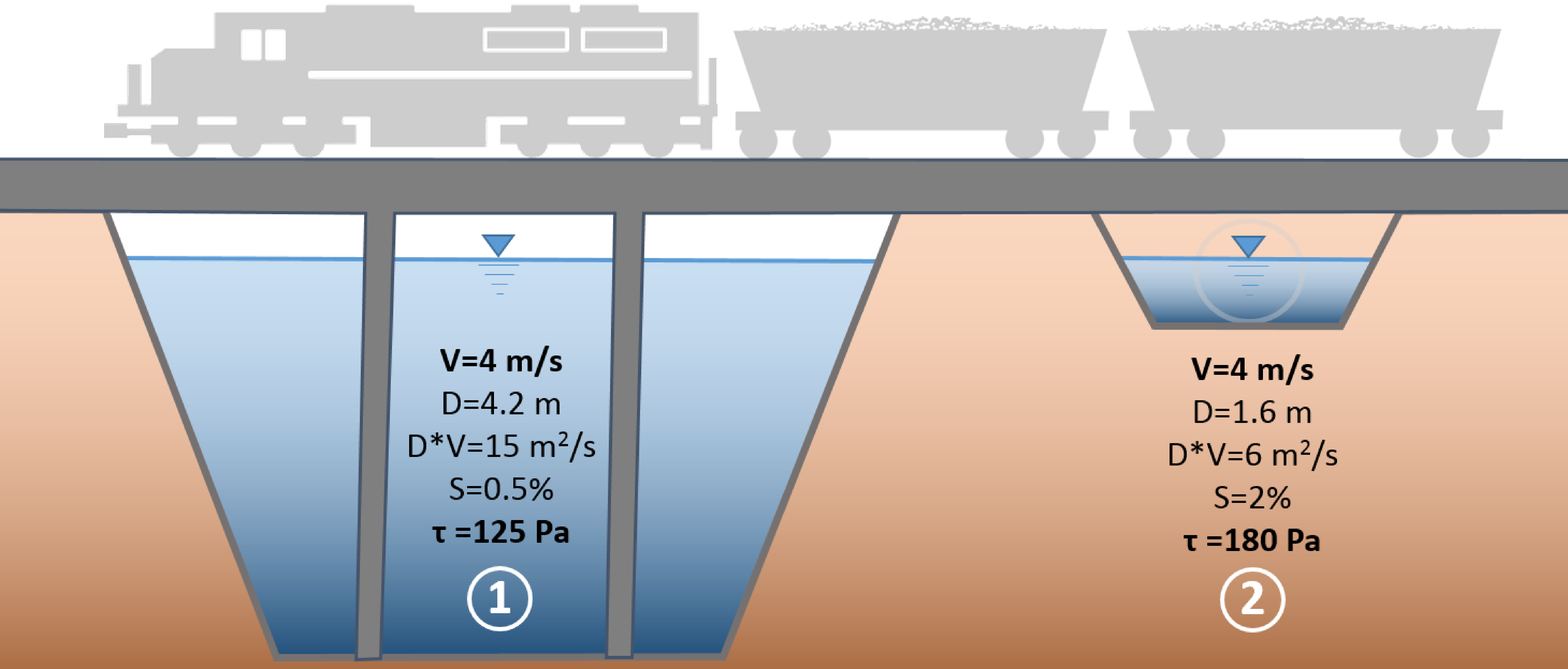
[From EMRRP, Fischenich 2001]



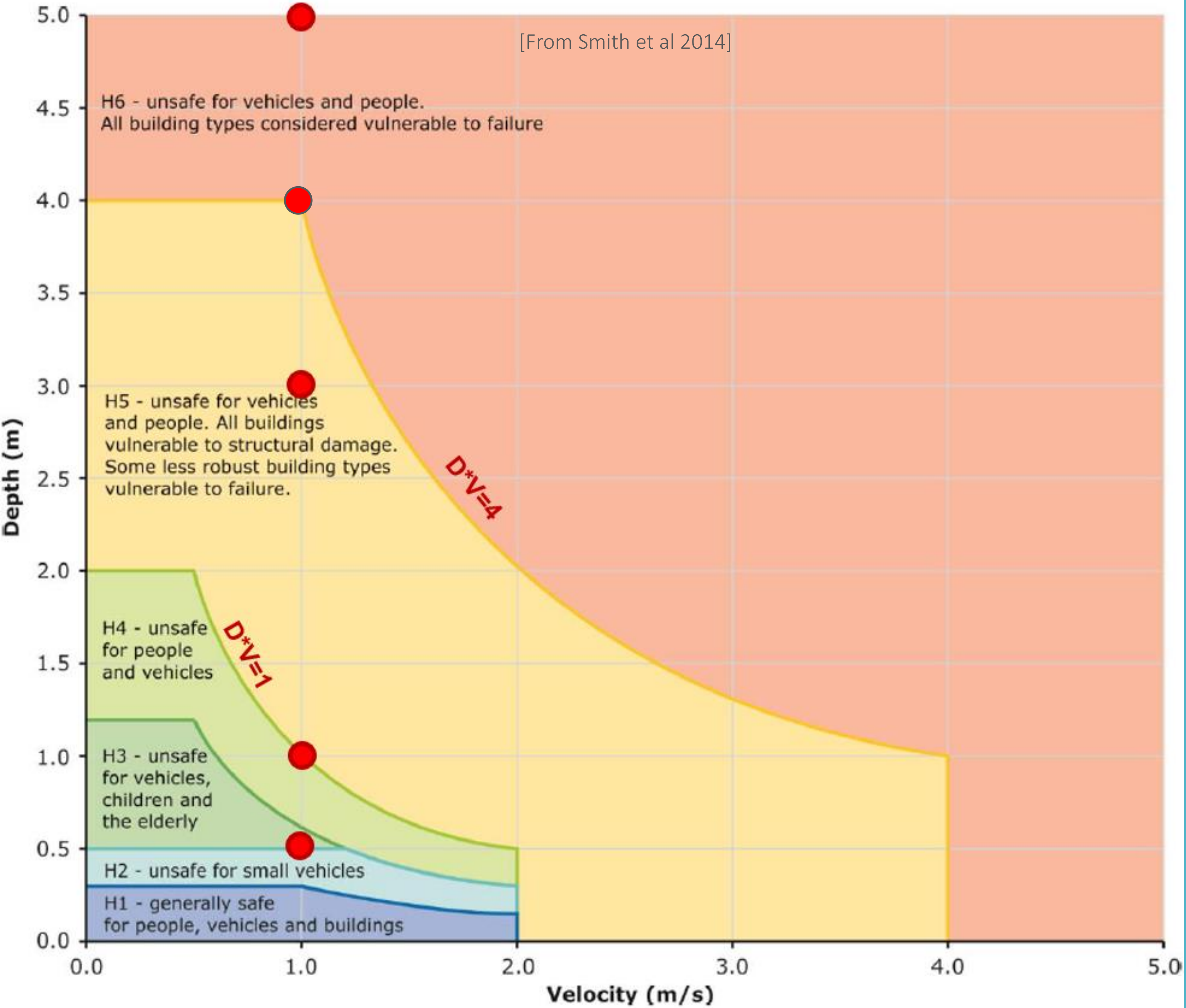



Comparison of rock sizes based on Austroads velocity criteria vs shear stress at 1mm/Pa + 25%
[From IMWA 2020]
0.1% Slope
0.5% Slope
1% Slope
2% Slope
Recommended D50 (mm)
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
Velocity
Shear
Velocity
Shear
Velocity
Shear
Velocity
Shear
2m Wide Channel 1m Deep
4m Wide Channel 1.5m Deep
6m Wide Channel 2m Deep

Note: Maintaining the same velocity in a shallower channel requires a steeper energy gradient. Shear calculated below is based on $\tau = \gamma R S$

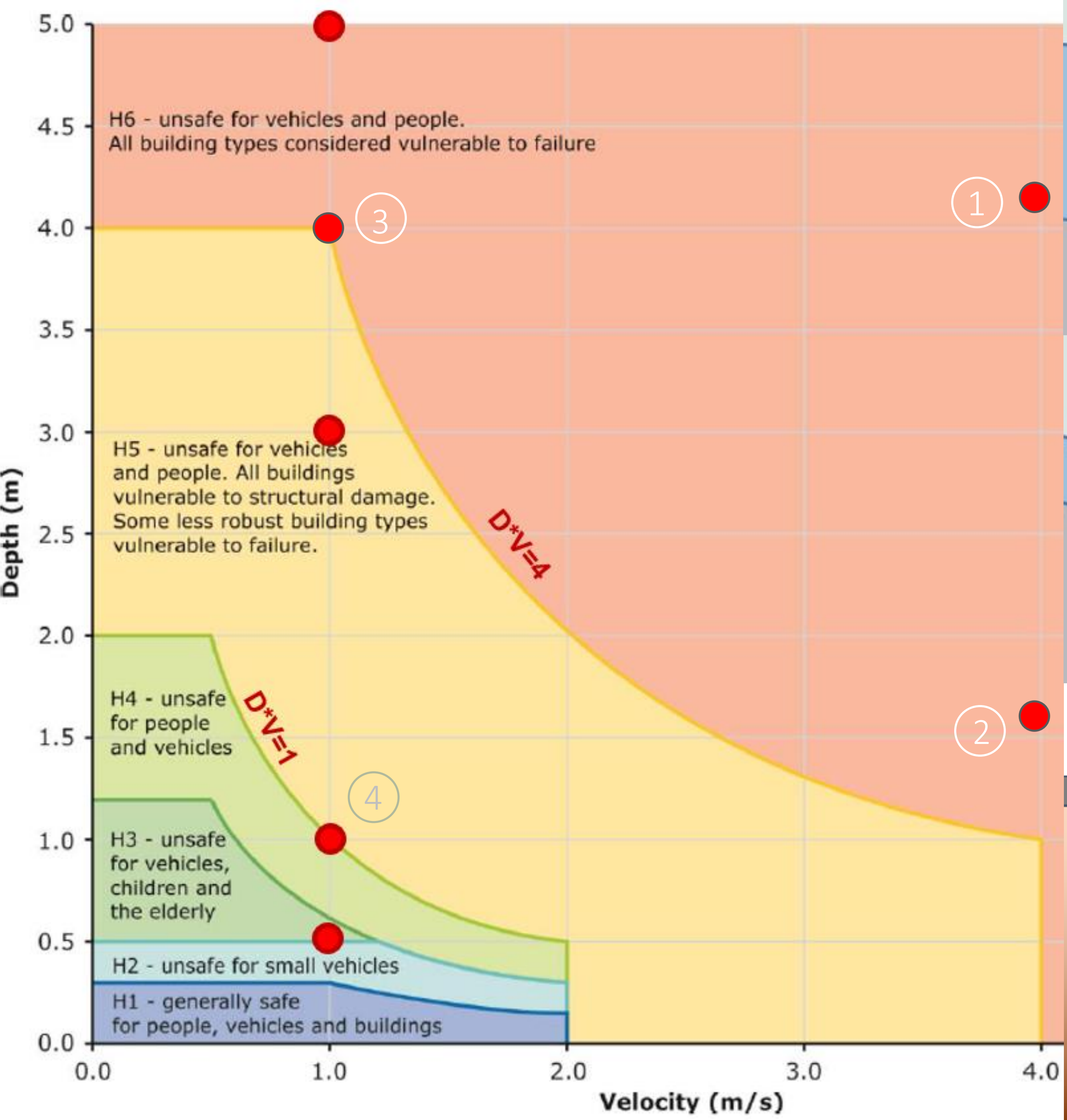


Velocity and shear stress for uniform flow

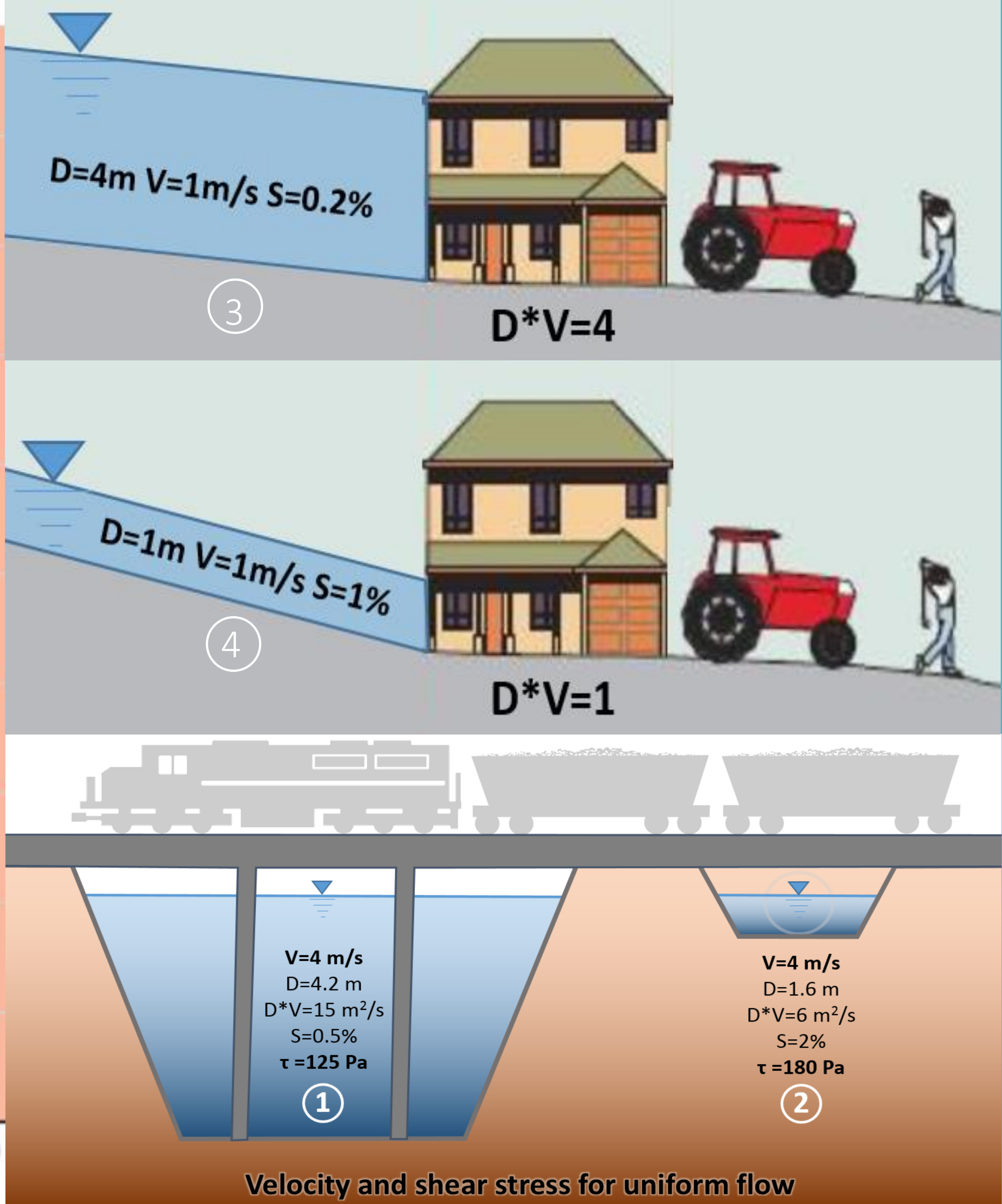


Flood Hazard

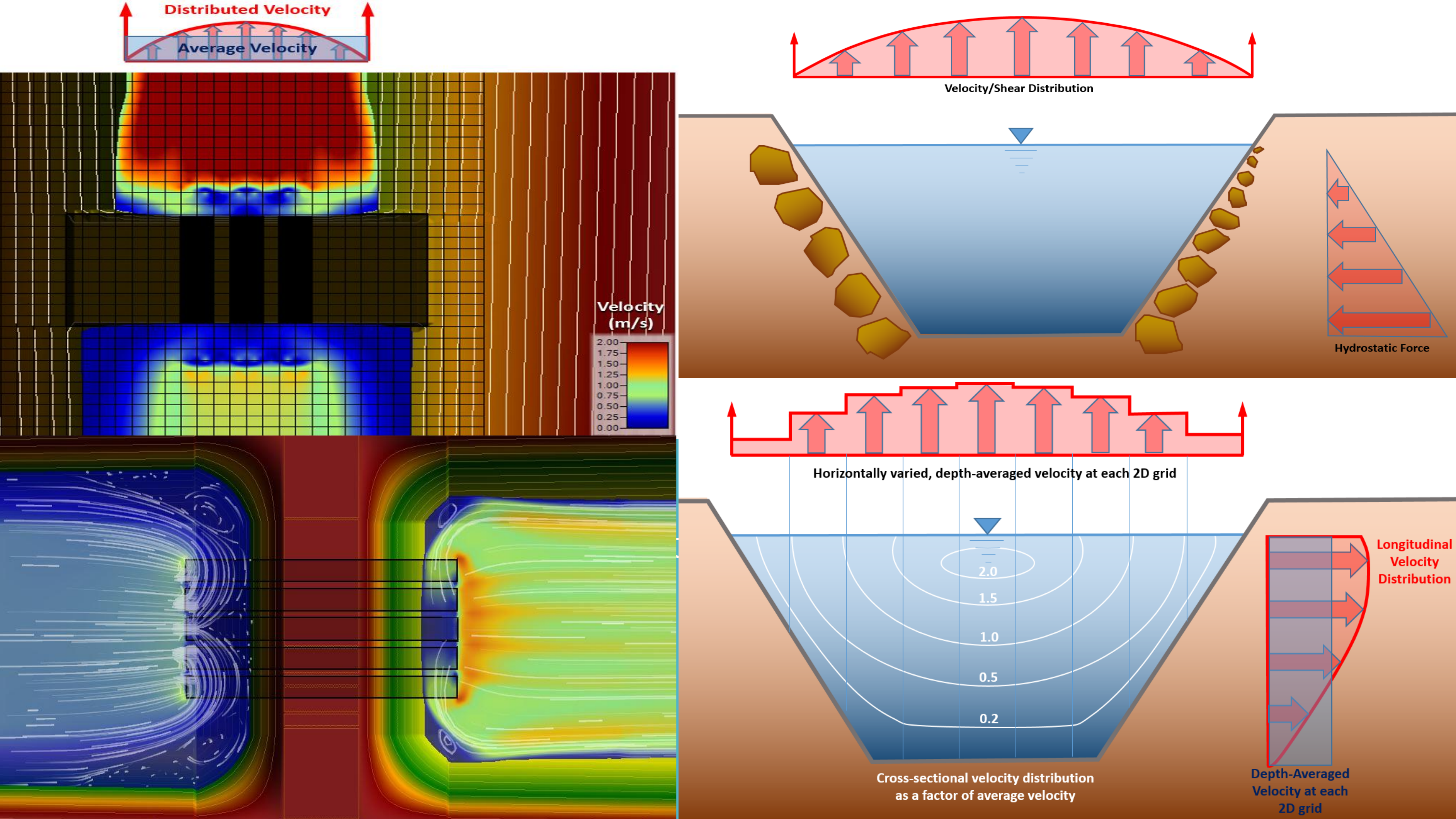
D*V

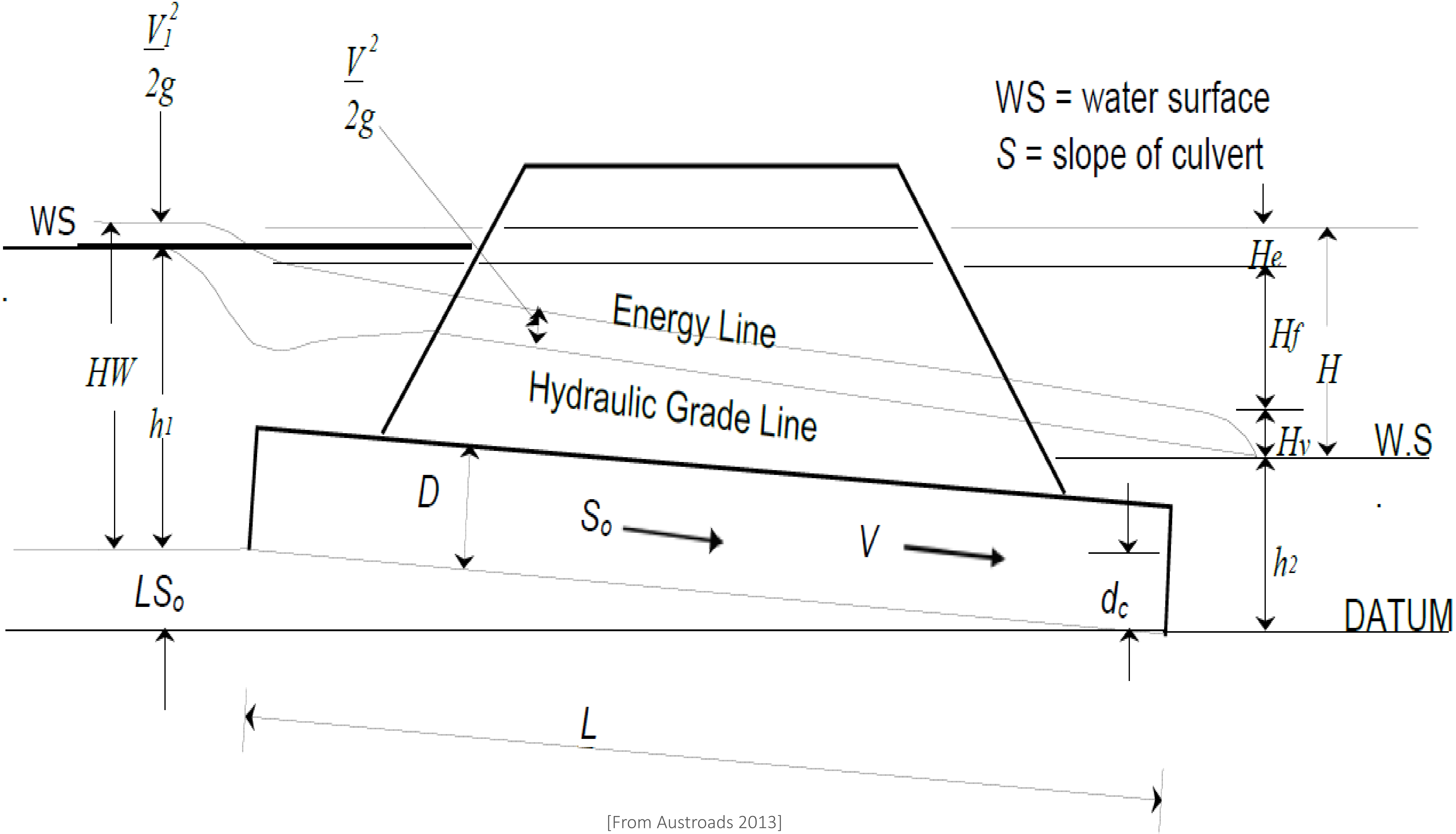


5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Depth (m)
0.0
1.0
2.0
3.0
4.0
Velocity (m/s)
H6 - unsafe for vehicles and people.
All building types considered vulnerable to failure
H5 - unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust building types vulnerable to failure.
H4 - unsafe for people and vehicles
H3 - unsafe for vehicles, children and the elderly
H2 - unsafe for small vehicles
H1 - generally safe for people, vehicles and buildings
D*V=4
D*V=1
1
2
3
4

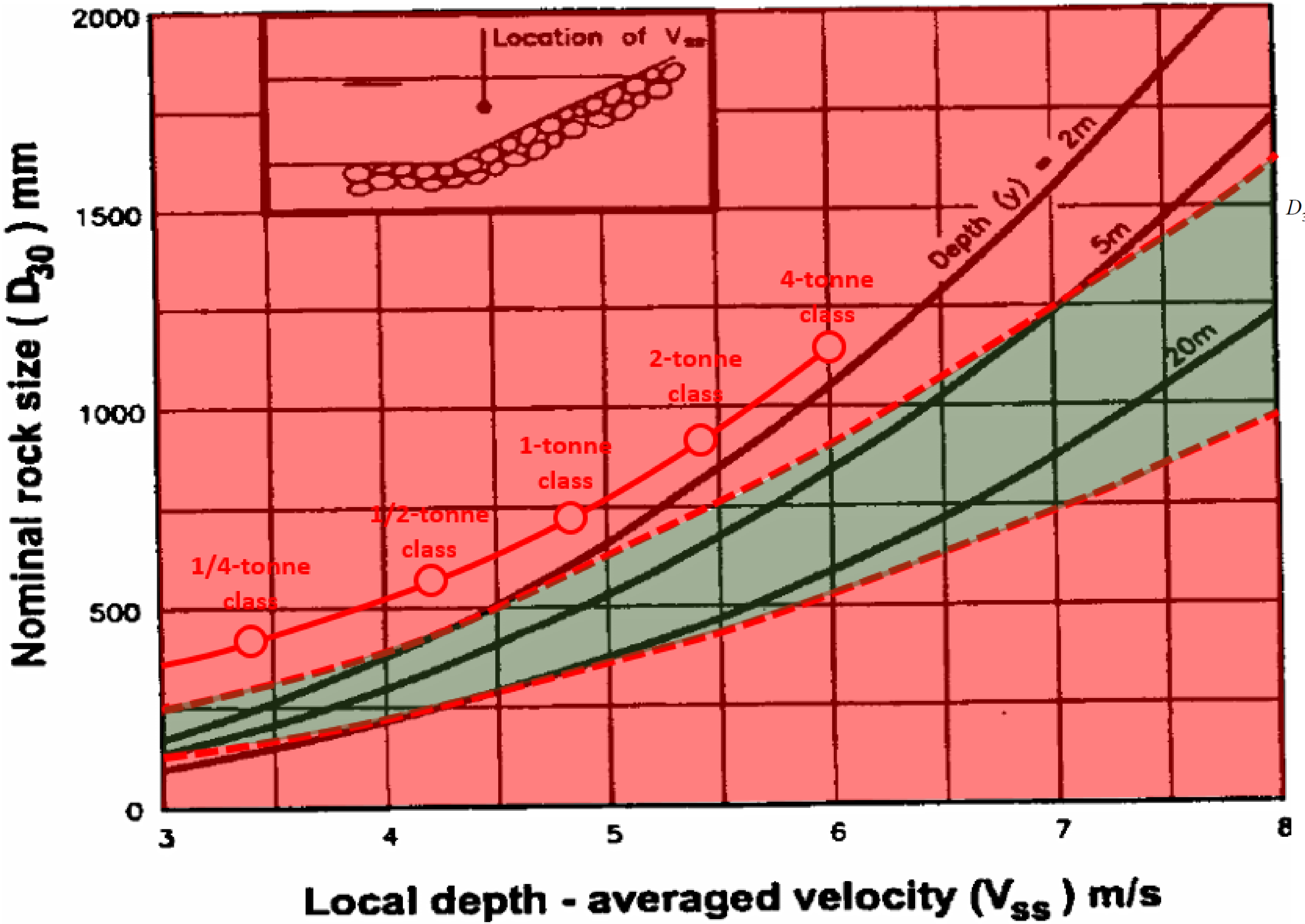


D=4m V=1m/s S=0.2%
3
D*V=4
D=1m V=1m/s S=1%
4
D*V=1
V=4 m/s
D=4.2 m
D*V=15 m²/s
S=0.5%
τ =125 Pa
1
V=4 m/s
D=1.6 m
D*V=6 m²/s
S=2%
τ =180 Pa
2
Velocity and shear stress for uniform flow


Distributed Velocity
Average Velocity
Velocity (m/s)
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
Velocity/Shear Distribution
Hydrostatic Force
Horizontally varied, depth-averaged velocity at each 2D grid
2.0
1.5
1.0
0.5
0.2
Longitudinal Velocity Distribution
Cross-sectional velocity distribution as a factor of average velocity
Depth-Averaged Velocity at each 2D grid



[From Austroads 2013]



BCMELP 2000 graphical representation of USACE 1994 equation:

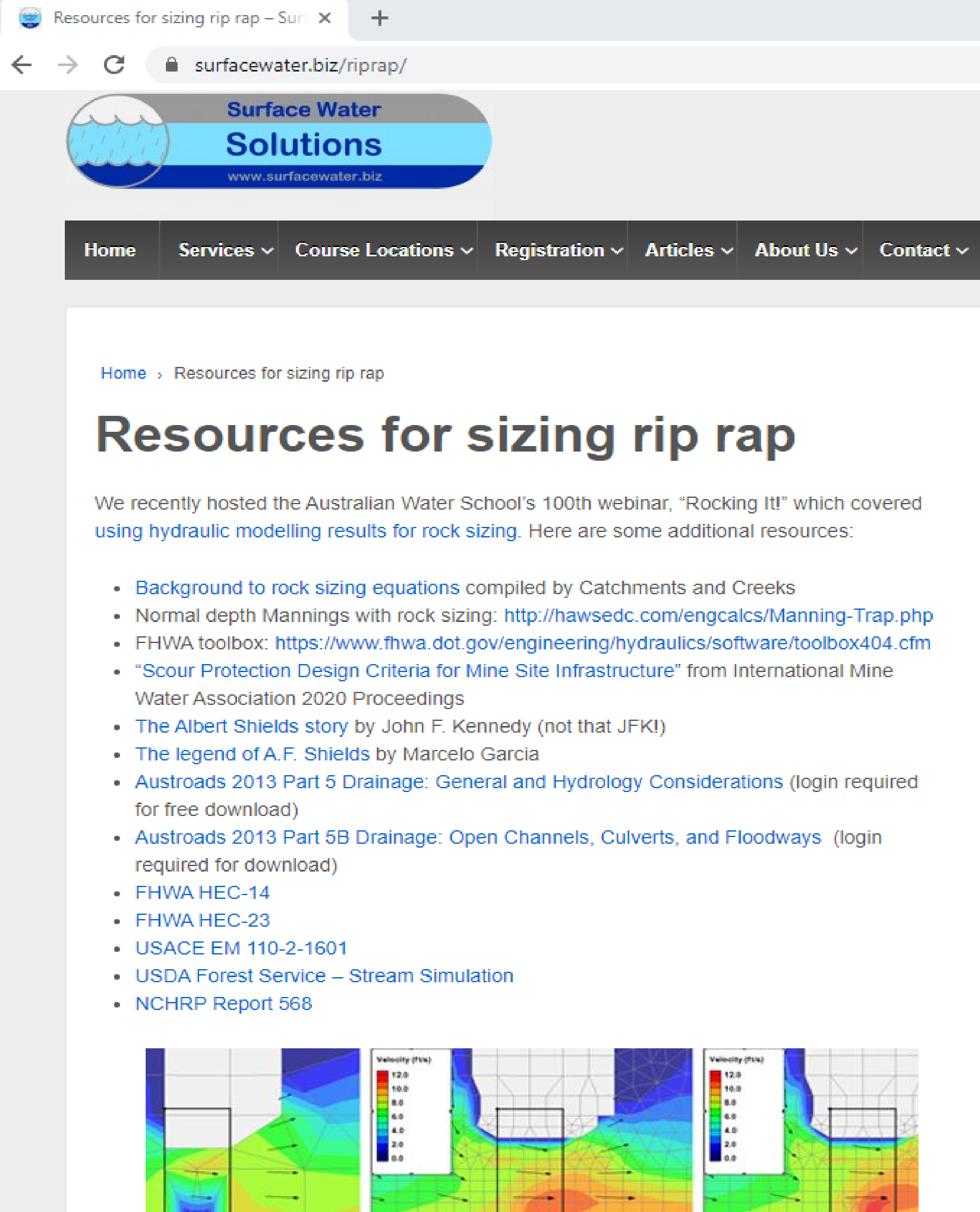
$$D_{30} = S_f C_s C_V C_T d \left[\left(\frac{\gamma_w}{\gamma_s - \gamma_w} \right)^{1/2} \frac{V}{\sqrt{K_1 g d}} \right]^{2.5}$$

Note: Maynord 1988 limits of applicability shown in green: $4 < D:D_{30} < 50$

Austroads 2013 shown in red, with rock size converted from D_{50} to D_{30}

Links to cited reports and additional resources:

www.surfacewater.biz/riprap/


Resources for sizing rip rap – Sur

surfacewater.biz/riprap/

Surface Water
Solutions
www.surfacewater.biz

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Home › Resources for sizing rip rap

Resources for sizing rip rap

We recently hosted the Australian Water School's 100th webinar, "Rocking It!" which covered using hydraulic modelling results for rock sizing. Here are some additional resources:

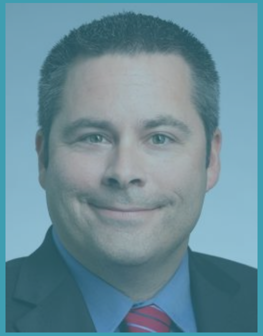
- Background to rock sizing equations compiled by Catchments and Creeks
- Normal depth Mannings with rock sizing: http://hawsedc.com/engcalcs/Manning-Trap.php
- FHWA toolbox: https://www.fhwa.dot.gov/engineering/hydraulics/software/toolbox404.cfm
- "Scour Protection Design Criteria for Mine Site Infrastructure" from International Mine Water Association 2020 Proceedings
- The Albert Shields story by John F. Kennedy (not that JFK!)
- The legend of A.F. Shields by Marcelo Garcia
- Austroads 2013 Part 5 Drainage: General and Hydrology Considerations (login required for free download)
- Austroads 2013 Part 5B Drainage: Open Channels, Culverts, and Floodways (login required for download)
- FHWA HEC-14
- FHWA HEC-23
- USACE EM 110-2-1601
- USDA Forest Service – Stream Simulation
- NCHRP Report 568

AWS Free Webinar: 2 December 2020

Rocking It!

Using hydraulic modelling results for rock sizing

Presented by:



Casey Kramer
Natural Waters

Krey Price
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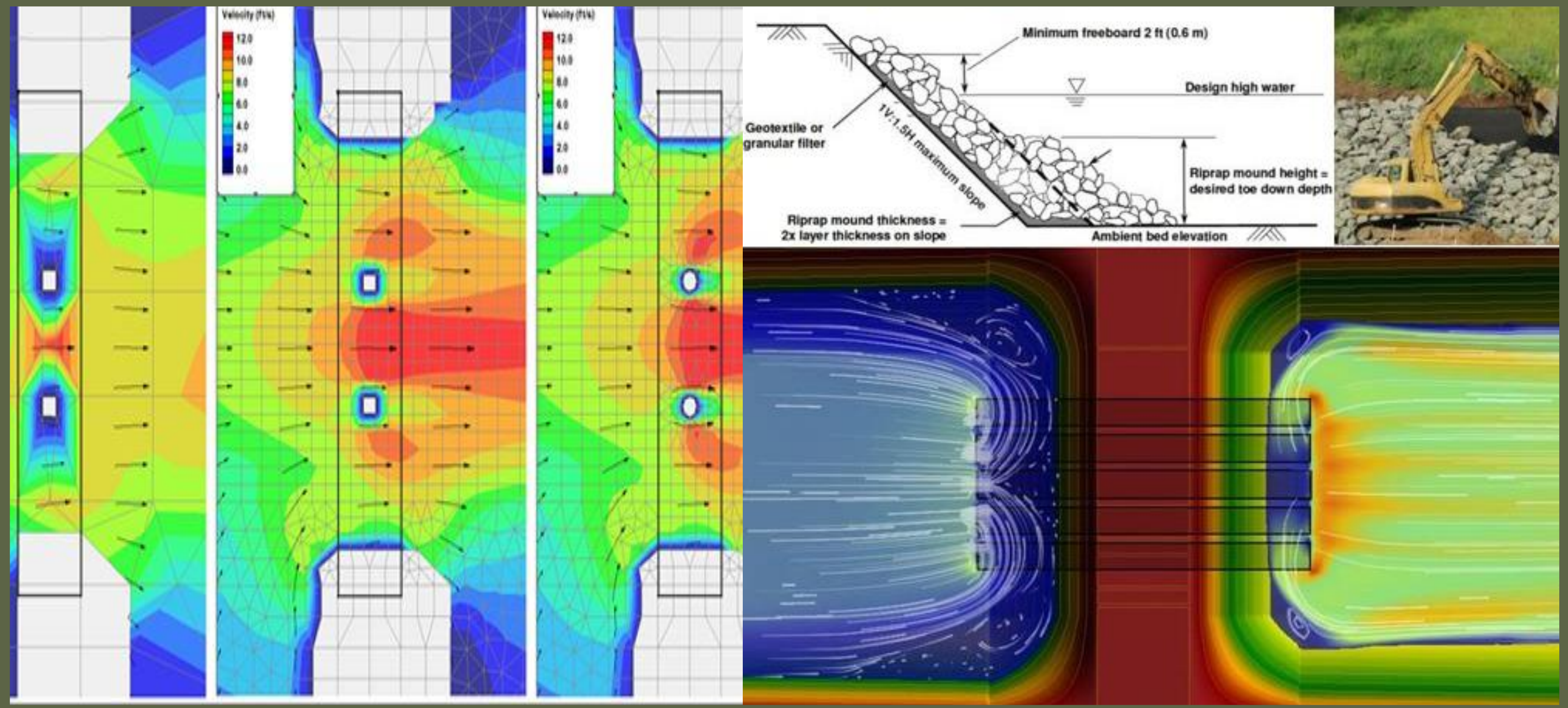
Water Solutions



Australian Water School

ROCKING IT!

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Australian Water School

Rocking It! Webinar

December 2nd, 2020

Casey Kramer, P.E.

NATURAL WATERS

Overview

Image Source: Casey Kramer

- Type of Project
- Selecting the Most Appropriate Hydraulic Model
- Terrain and Mesh Resolution
- Selecting the Most Appropriate Rock Sizing Equation
- Importance of Understanding Applicability and Limitations
- Various Rock Sizing Methods
- Typical Design Components
- Selecting Materials
- Some References

NATURAL WATERS

Type of Project

- Prior to any hydraulic modeling or design calculations, the designer should clearly identify the type of project, for example:
  - Bank protection/stabilization
  - Energy dissipation
  - Bridge pier protection
  - Bridge abutment protection
  - Stream/river restoration
  - Fish passage water crossing
  - Coastal applications
  - Etc.

Image Source: Casey Kramer

NATURAL WATERS

Selecting Most Appropriate Hydraulic Model

- Some of the key questions in model selection should be:
  - What are the key hydraulic processes observed at the project site?
  - What model extents are needed to properly determine flow characteristics at project site?
  - What resolution is needed to adequately represent hydraulic processes necessary for engineering problem being addressed?
  - What other model inputs are necessary?

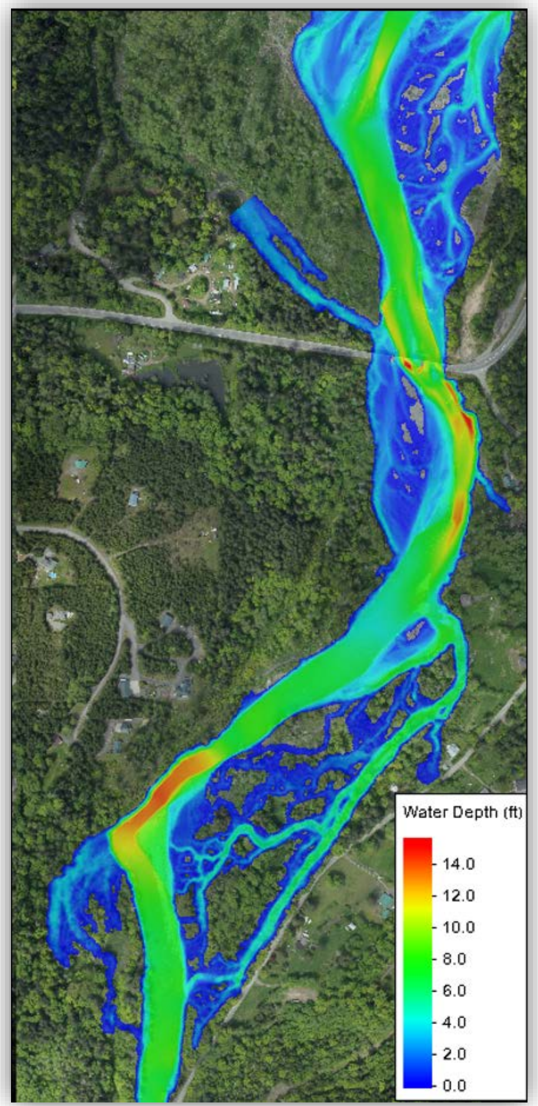

Image Source: Casey Kramer

NATURAL WATERS

Example – Selecting Appropriate Model

Image Source: Casey Kramer

Example – Selecting Appropriate Model

Image Source: Casey Kramer

NATURAL WATERS

Example – Selecting Appropriate Model

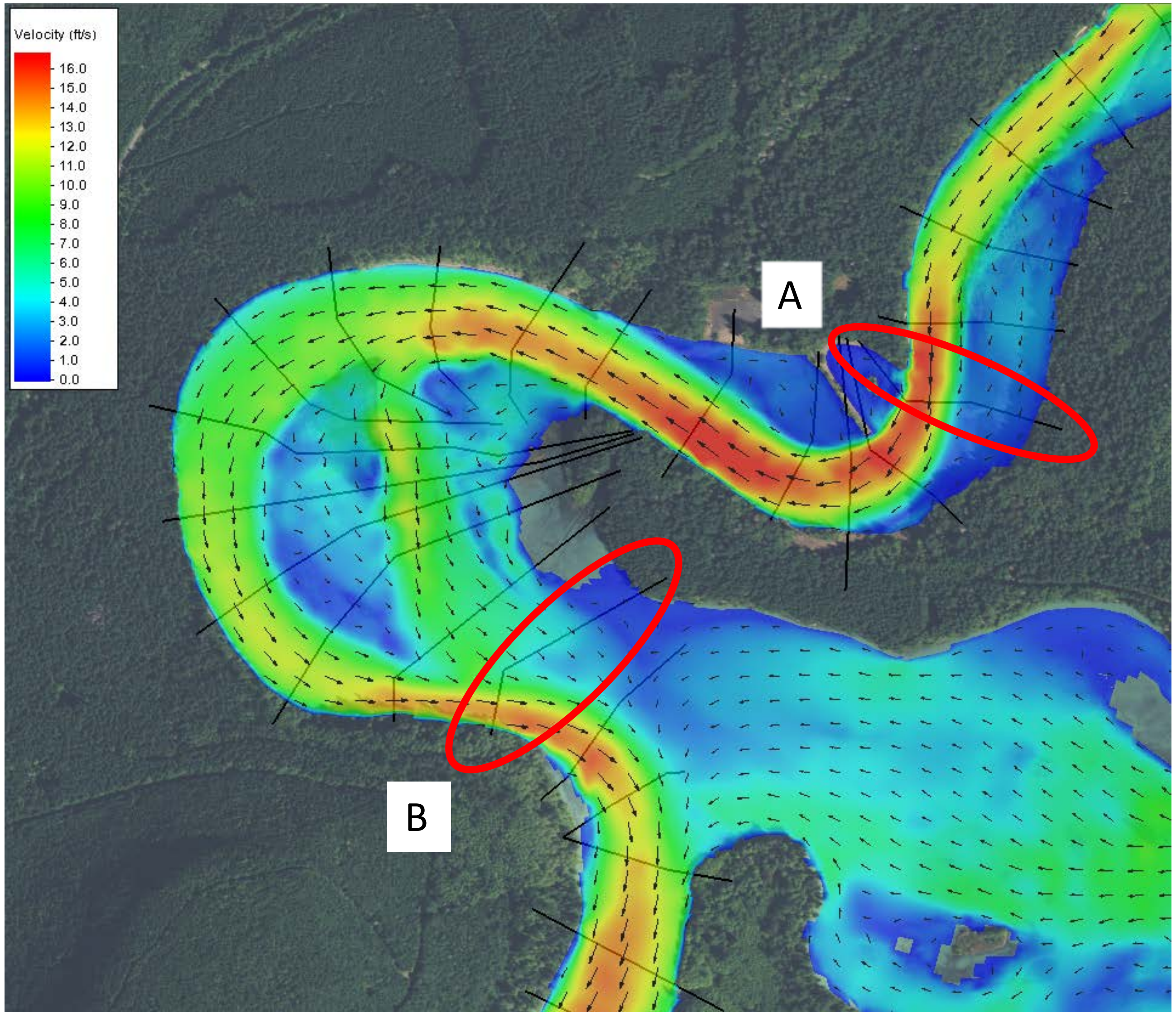

Image Source: Casey Kramer

Cross Section A

- Minimum Velocity = 0
- Average Velocity = 4.5 ft/s
- Max Velocity = 16 ft/s

Cross Section B

- Minimum Velocity = 0.2 ft/s
- Average Velocity = 4.9 ft/s
- Max Velocity = 14.3 ft/s

Terrain and Mesh Resolution

- Terrain and mesh resolution should be carefully evaluated to ensure:
  - Hydraulic controls are properly accounted for in terrain data and mesh
  - Mesh accurately represents the terrain data
  - Alignment with the spatial resolution of the hydraulic variables needed for the analysis (e.g. floodplain inundation vs bridge hydraulics)

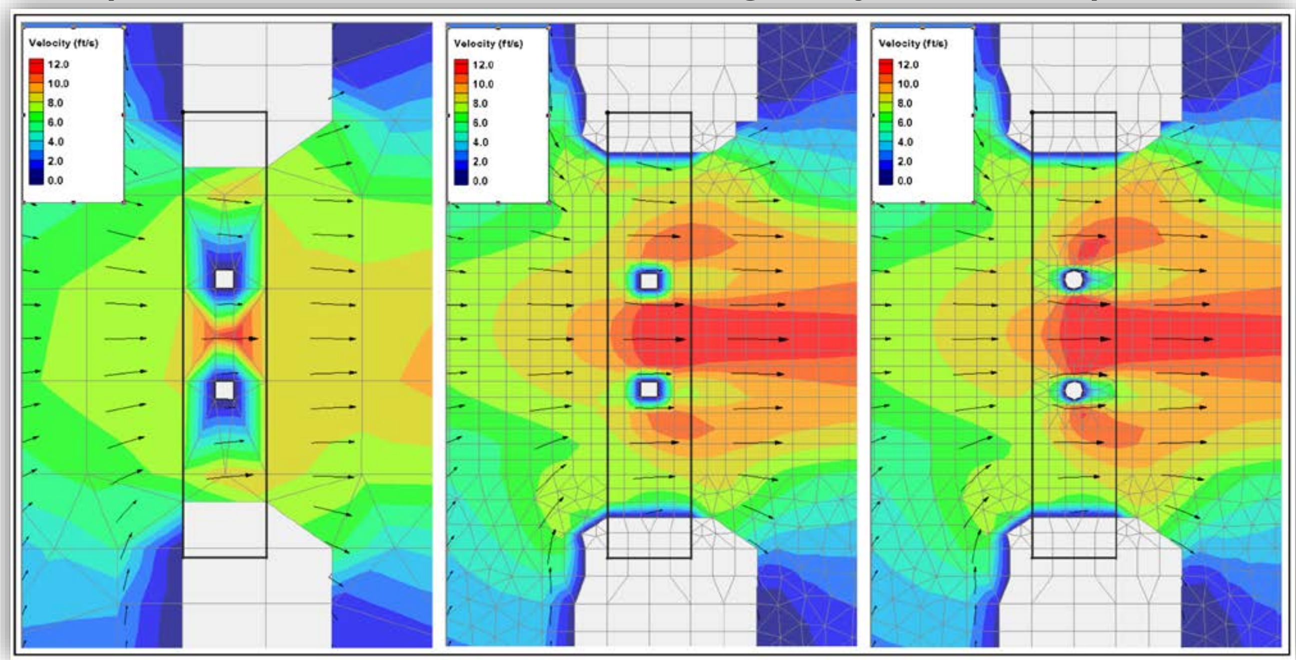

Image Source: FHWA

Various Rock Sizing Methods

- Some rock sizing methods include but are not limited to:
  - Bank protection/stabilization
    - Maynord/USACE EM-1601/FHWA HEC 23
  - Bridge Pier and Abutment Protection
    - Isbash/FHWA HEC 23
  - Stream/river restoration and fish passage water crossing design
    - Modified Shields (shear stress)
    - Bathurst (critical discharge)
  - Austroads 2013

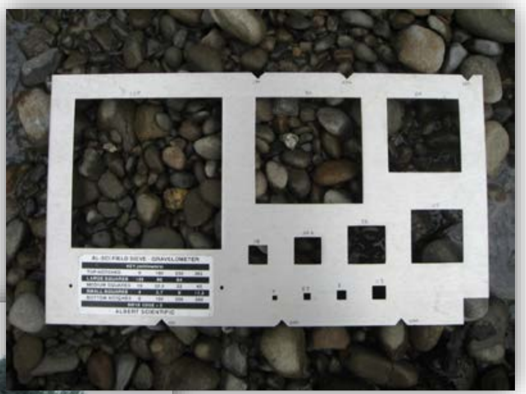

Image Sources: Casey Kramer

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Selecting the Most Appropriate Rock Sizing Equation

- Large variety in rock sizing equations depending on project, examples include:
  - Bank protection/stabilization
  - Energy dissipation
  - Bridge pier protection
  - Bridge abutment protection
  - Stream/river restoration
  - Fish passage water crossing
  - Coastal applications
  - Etc.

Image Sources: Casey Kramer

Importance of Understanding Applicability and Limitations

- Designer needs to understand key assumptions of each rock sizing equation
- Applicability and limitations for each equation may include:
  - Channel bed or energy grade slope
  - Relative Submergence
  - Sediment size (e.g. D_{16}, D_{50}, D_{84})
  - Uniformity of material (e.g. D_{84} / D_{16})
  - Shape of material (e.g. round vs angular)
  - Etc.

Image Sources: Casey Kramer

Typical Design Components

- Typical design components may include:
  - Filter (Fabric or granular)
  - Specified material layer thickness
  - Specified material spatial extents
  - Specified material elevation extents
  - Specified material embedment depths
  - Transition detail

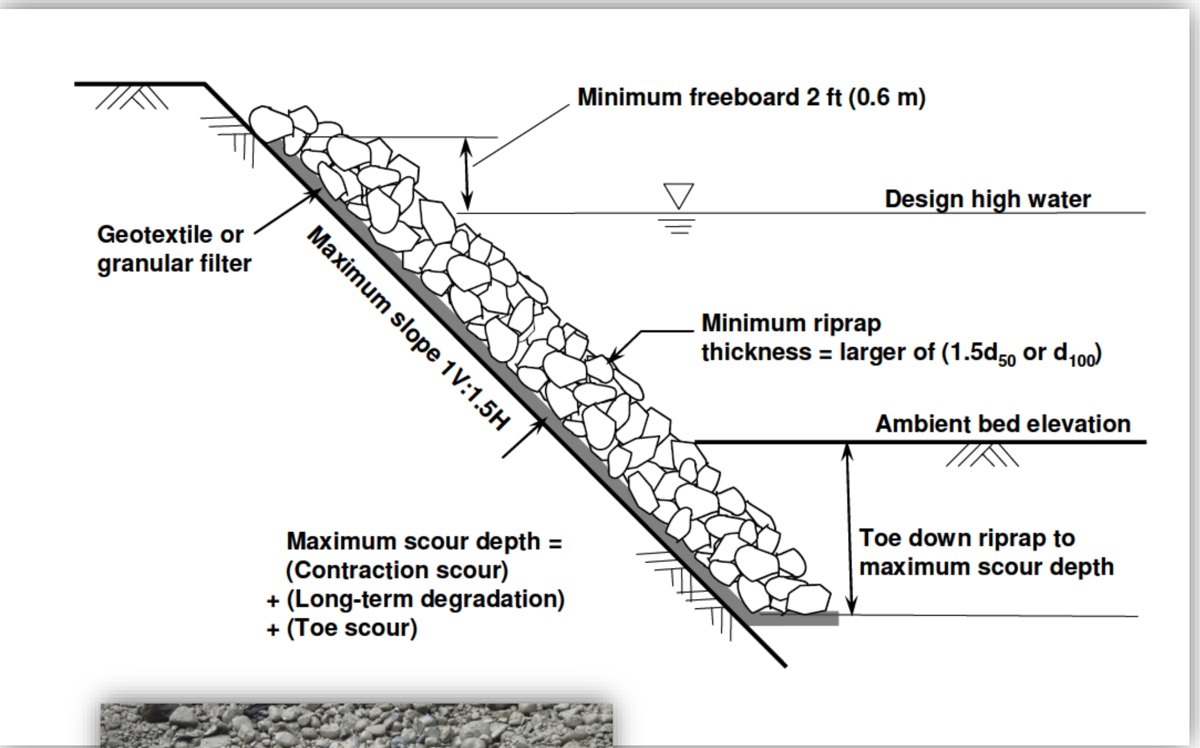

Image Source: FHWA

Image Source: Casey Kramer

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Selecting Materials

- After an appropriate hydraulic model has been developed and correct rock sizing method is applied, selection of materials is a critical step

- Material specifications should include at a minimum:
  - Minimum allowable durability
  - Minimum allowable specific gravity
  - Allowable range of sizes and gradation
  - Allowable range of particle shape

Image Sources: Casey Kramer

Some References

- FHWA HEC 15
- FHWA HEC 23
- FHWA Hydraulic Toolbox
- USACE EM 1110-2-1601
- NCHRP Report 568
- USDA Forest Service – Stream Simulation
- WSDOT Standard Specifications
- FHWA 2D Hydraulic Modeling for Highways in River Environment
- Austroads 2013

Conclusions

Image Source: Casey Kramer

- Type of Project
- Selecting the Most Appropriate Hydraulic Model
- Terrain and Mesh Resolution
- Various Rock Sizing Methods
- Selecting the Most Appropriate Rock Sizing Equation
- Importance of Understanding Applicability and Limitations
- Typical Design Components
- Selecting Materials
- Some References

Image Source: Casey Kramer

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