Bridge Design – How Much Water?

BF278 – Hwy 2A over Battle River near Ponoka

- Why does it matter?
- Typical bridge
- Looks like lots of capacity, when flow is low

Bridge Design – How Much Water?

July 1990 flood:

- More than 20 times the flow
- Water over bridge and approach road – closure, potential damage, potential increased flooding upstream

Bridge Design – How Much Water?

- After flow receded, large void was observed behind

Bridge Design – How Much Water?

Hwy 734 over Simonette River near Grande Prairie

- 1983 Flood
- Holding up well

Bridge Design – How Much Water?

Loss of Bridge:

- Hwy 734 over Simonette River near Grande Prairie
- 1987 Flood
- Buoyant and horizontal force

Bridge Design – How Much Water?

Superstructure carried away and damaged

Bridge Design – How Much Water?

Hwy 33 over Island Ck near Kinuso

- Post 1983 flood
- Some repairs to abutment

Bridge Design – How Much Water?

Loss of Road:

- Hwy 33 over Island Ck near Kinuso
- Bridge still standing, but is now an island

Bridge Design – How Much Water?

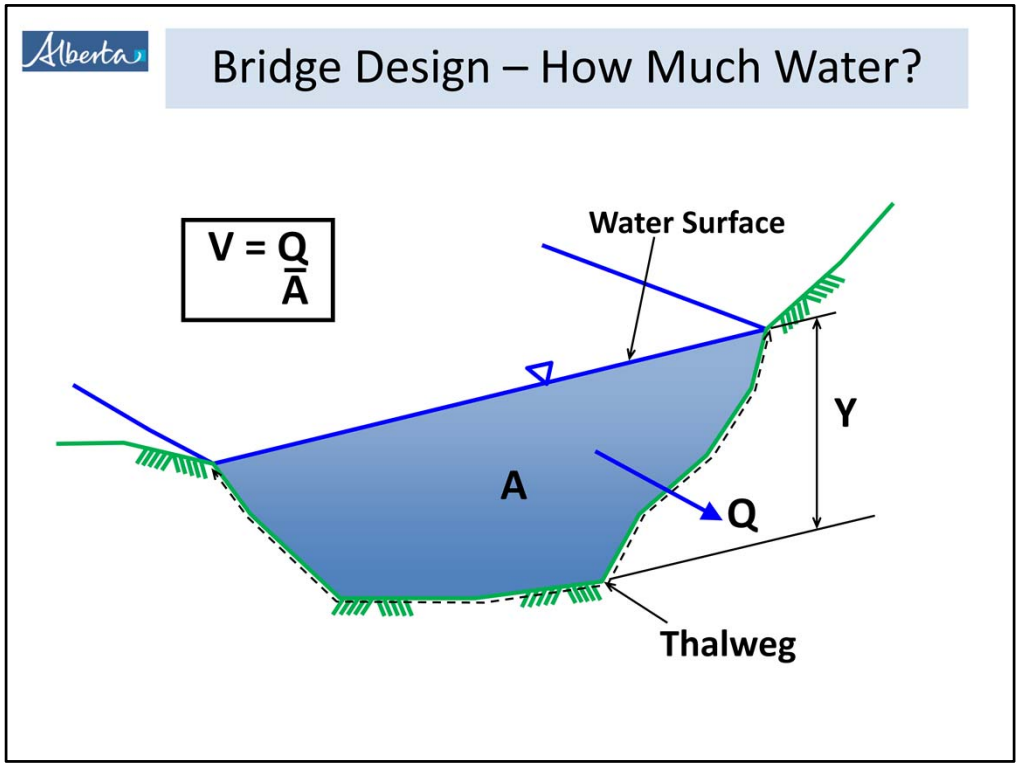
Constrictive opening - Note :

- Higher water levels upstream (flooding)

Bridge Design – How Much Water?

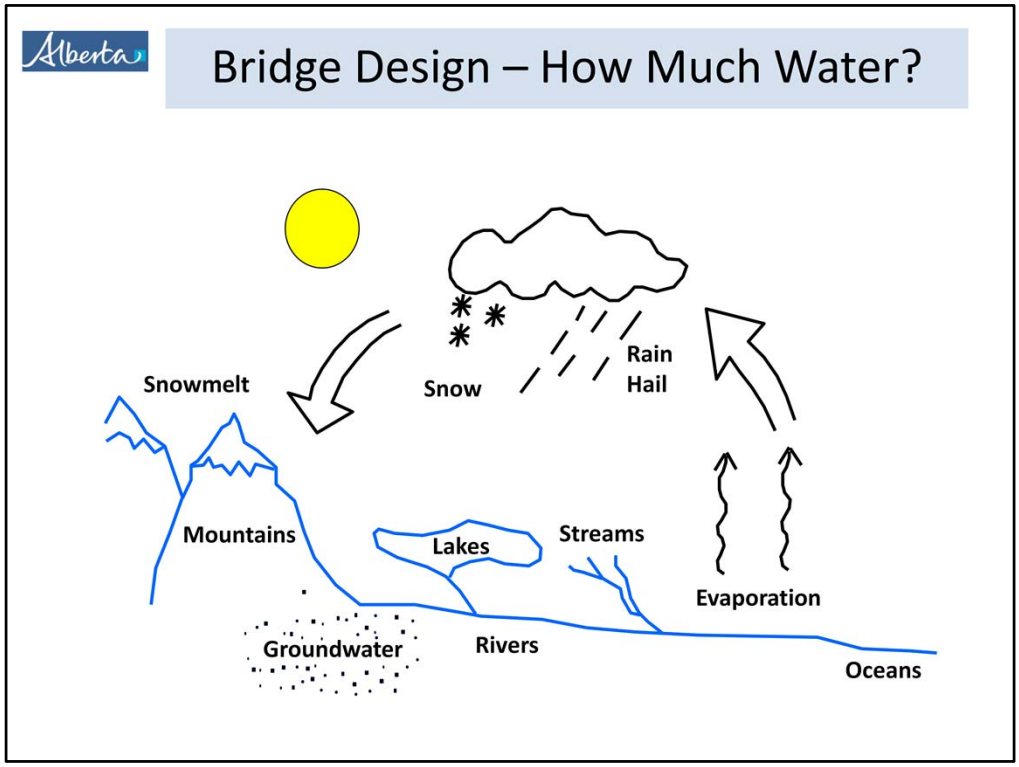
Constrictive opening - Note :

- Higher velocity d/s - erosion

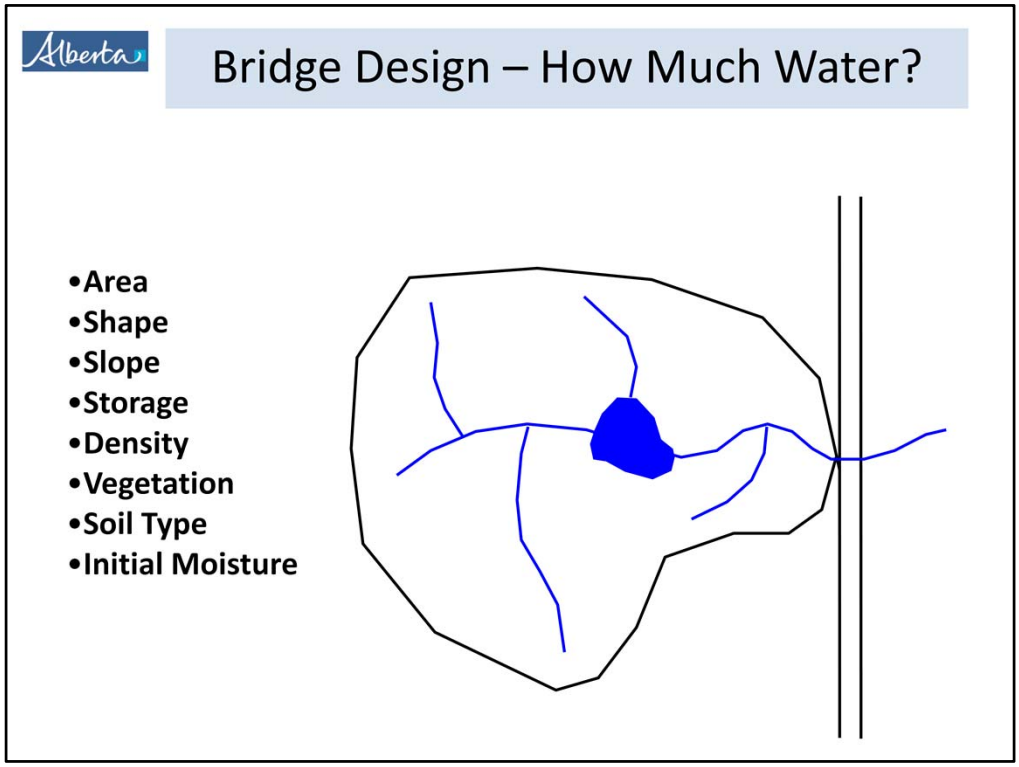


Some basic Definitions:

- Q – flow (discharge), volume of water passing section in given amount of time – cms
- Y – flow depth (m)
- V – mean flow velocity (m/s)



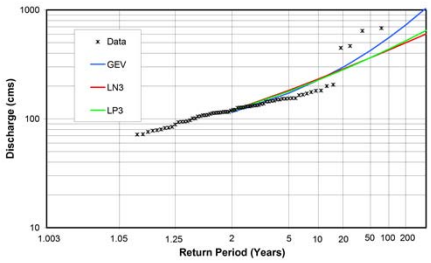
Hydrologic Cycle

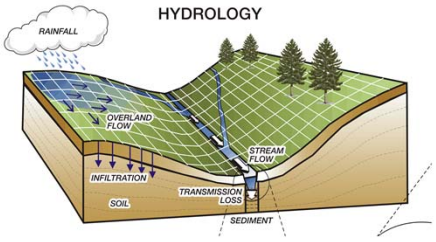


Many complex parameters affect runoff

Bridge Design – How Much Water?

Options





Statistics

Model

Frequency Analysis – no connection with Physics:

- No true distribution
- Most data not floods
- Very sparse data
- Extreme data very inaccurate
- Why 1:100?

Hydrologic Model – too complex:

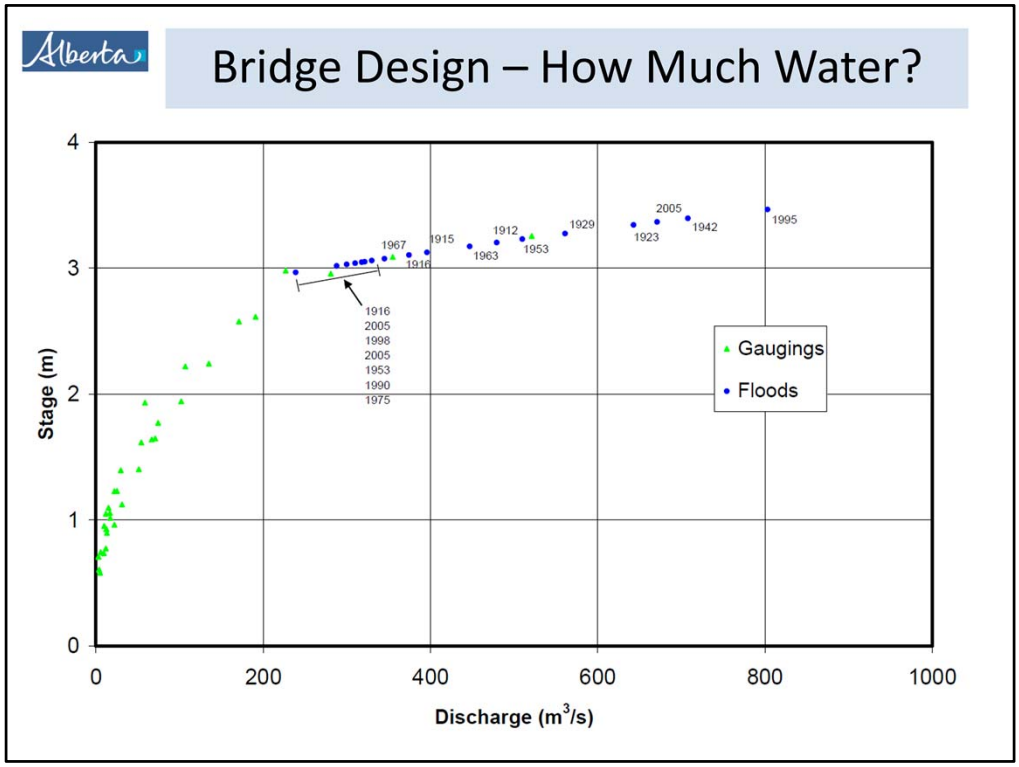
- Diversity of parameters and inputs
- Calibration data not available
- Input vs output – no correlation
- Still need a design input

Bridge Design – How Much Water?

Stream	Location	Year	Flow (cms)	Stage (m)	Stream	Location	Year	Flow (cms)	Stage (m)
Oldman	Lethbridge	1995	4700	8.5	N. Sask.	Edmonton	1899	6000	13.0
		1908	4500	8.3			1915	5800	12.8
		1948	3500	7.5			1986	4500	11.6
		1953	3100	7.1			1952	3750	10.8
		2013	2400	6.3			2013	2800	9.5
Bow	Calgary	1879	2250	4.5	Athabasca	Athabasca	1954	5700	7.1
		1897	2250	4.5			1944	5000	6.8
		2013	1700	4.1			1971	4600	6.5
		1902	1550	4.0			1986	4500	6.5
		1932	1500	4.0			1980	4300	6.3
Red Deer	Red Deer	1915	1900	6.6	Smoky	Watino	1990	9400	10.4
		2005	1500	5.9			1982	9200	10.2
		1954	1500	5.9			1972	9000	10.0
		2013	1300	5.5			1987	7100	8.7
		1952	1250	5.4			1965	5500	7.6

Actual observations of extreme events:

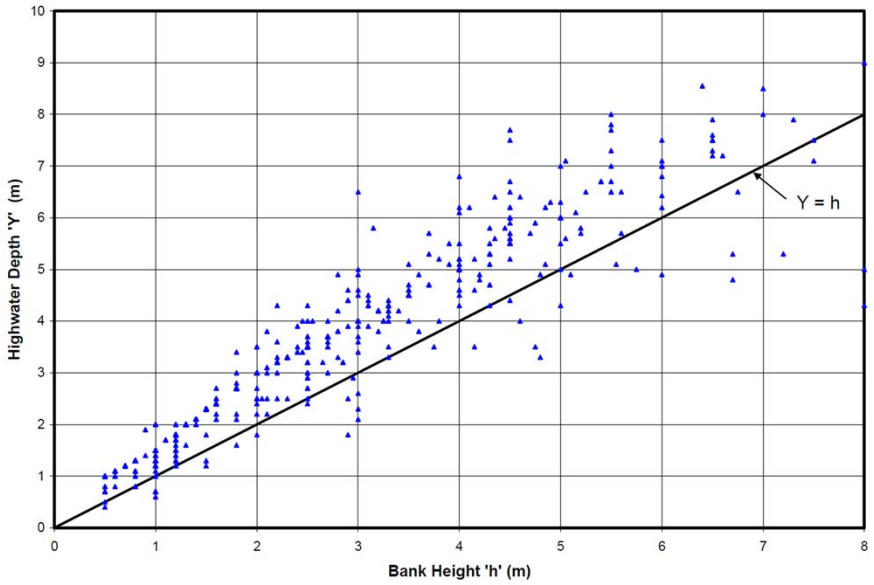
- Longest records in province
- All major basins represented
- Largest floods trend to a certain range



Extreme Example – Highwood River at High River:

- Within 0.3 – 0.5m of highest flood ~ 18 times in 100 years
- Assigned frequency is irrelevant, we know the magnitude

Bridge Design – How Much Water?



Analysis of HIS DB Data:

- Highest observed HW related to bank height
- Most within a certain amount above bank height - flood

Bridge Design – How Much Water?

Physics:

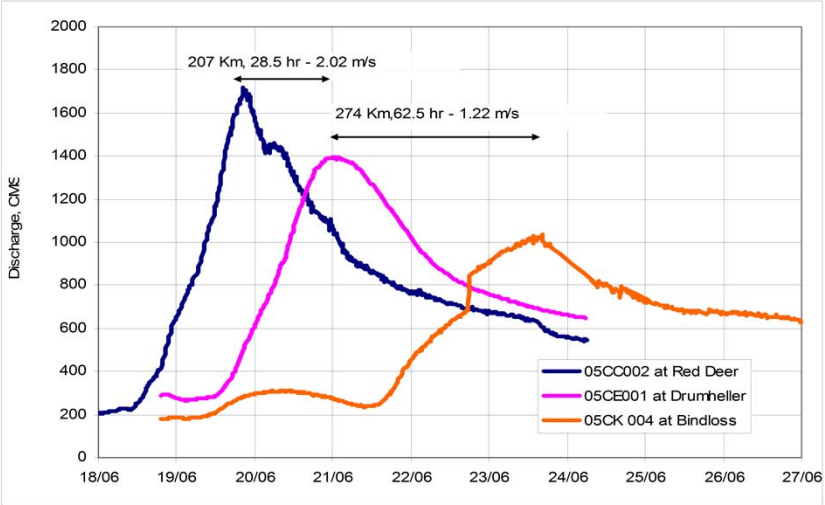
- Most channels have trapezoidal shape up to bankfull
- Beyond this level, much of water goes into storage
- Does runoff make the channel or does channel control the runoff? - Yes

Bridge Design – How Much Water?

Hwy 18 over Pembina River – 1986 flood:

- Significant storage of flood water on floodplain
- Acts as reservoir – routes peak flows

Bridge Design – How Much Water?



Example of flood hydrograph routing:

- Peak drops as flood wave passes
- Hydrograph spreads out
- Water enters floodplain storage before peak and then re-enters stream after peak

Bridge Design – How Much Water?

Hydrotechnical Design Guidelines

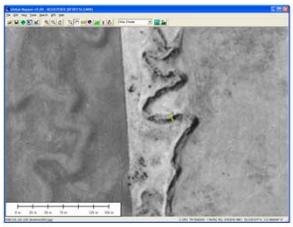
Component	Governs	% System
Channel Capacity	Most channels	> 80%
Historic HWM	Large streams	~ 10%
Runoff Potential	Small basins	< 5%

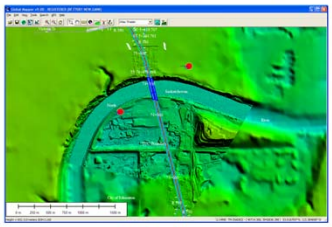
HDG:

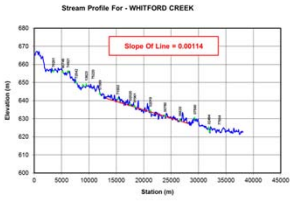
- Established in 2001
- 3 components
- Examples provided for > 1500 bridge sites in HIS
- Historic HWM seldom >> Qcc, usually confirms
- Runoff Potential – seldom governs, important when it does

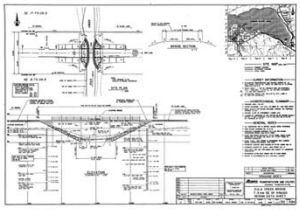
Bridge Design – How Much Water?

Channel Capacity









Typical Channel Parameters:

- Typical
- GIS – B,h,T,S
- Airphotos, DEM (Lidar)
- DEM – Profiles – S
- Survey, Drawings
- Photos

Bridge Design – How Much Water?

Channel Capacity

				h	Y_{cc}	Y_{spec}
S	0.00500		Y	2.5	3.5	0.51
B	10.0		A	38	58	5.6
h	2.5		d	1.9	2.9	0.5
T_h	20		V	2.6	3.4	1.0
Roughness			Q	96.1	196.2	5.7

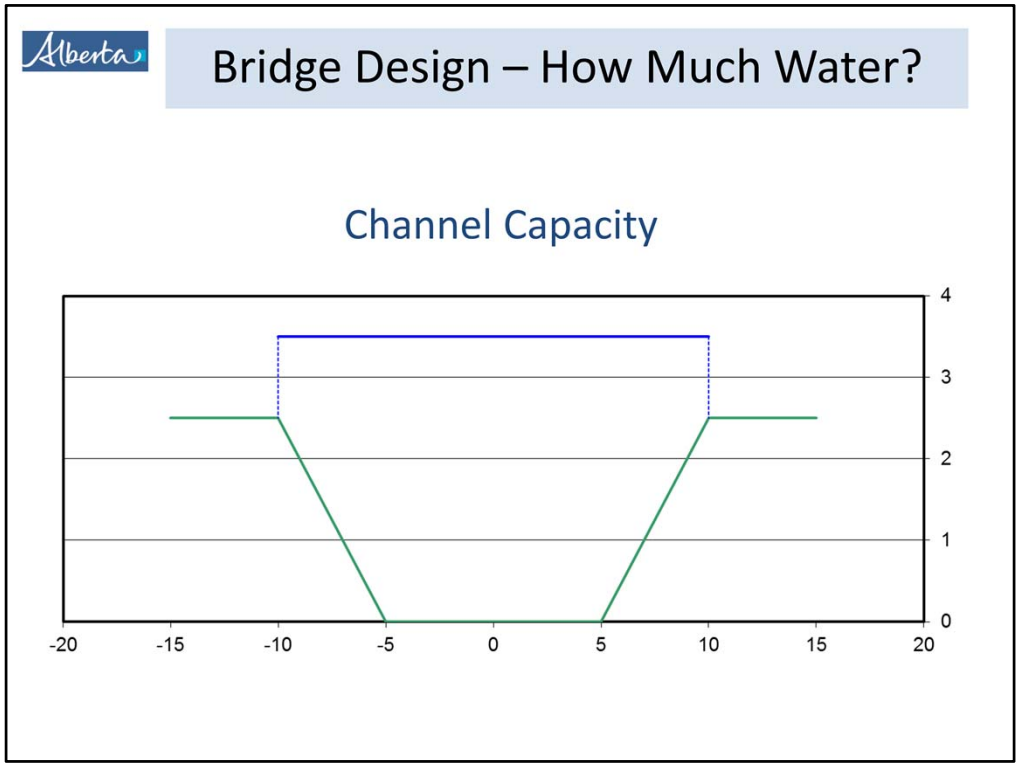
Parameters:

- S,B,h,T – geometric
- Roughness – Manning (guidance) or AT (B > 10m)

Output

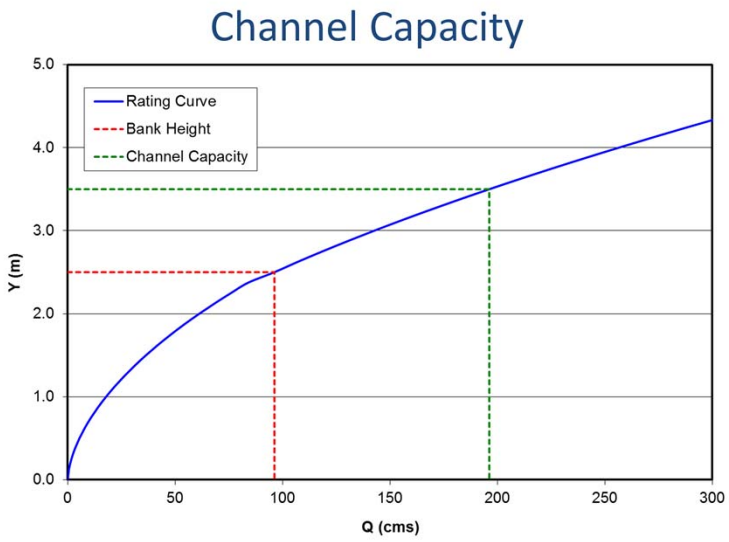
- Y,V,Q for h, cc, and specified

Bridge Design – How Much Water?



- Depth to activate floodplain storage
- Only include flow area > channel
- Floodplain flow low – not d/s, not continous path, high relative roughness, in and out of channel

Bridge Design – How Much Water?

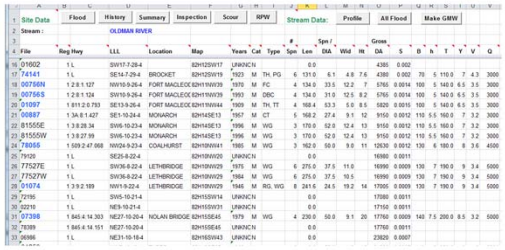


Typical Rating Curve:

- Qcc >> Qh
- Increase in A and V due to increase in Y

Bridge Design – How Much Water?

Historic Highwater - AT

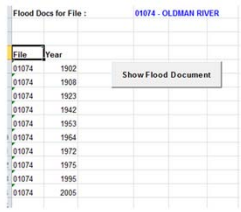


Site Data	Flood	History	Summary	Inspection	Scour	RPW	Stream Data:	Profile	All Flood	Make GRW
Stream :	OLDMAN RIVER									

File	Reg Hwy	LLL	Location	Map	Years	Cat	Type	# Spn	Spn / Len	DIA	Wid	Ht	Gross DA	S	B	h	T	Y	V	Q
01602		1 L		SW17-7-28-4	82H125W17	UNKNCN			0.0				4385	0.002						
74141		1 L		SE14-7-29-4	BROCKET	82H125W19	1923	M	TH, PG	6	131.0	6.1	4.6	7.6	4380	0.002	70	5	110.0	7	4.3	3000
00766N		1 2.8 1.127		NW10-9-26-4	FORT MACLEOD	82H11NW39	1970	M	FC	4	134.0	33.5	12.2	7	5765	0.0014	100	5	140.0	6.5	3.5	3000
00766S		1 2.8 1.124		SW10-9-26-4	FORT MACLEOD	82H11NW39	1993	M	DBC	4	134.0	31.0	12.5	8.2	5765	0.0014	100	5	140.0	6.5	3.5	3000
01097		1 811.2 0.793		SE13-9-26-4	FORT MACLEOD	82H11NW44	1909	M	TH, TT	4	168.4	53.3	5.0	8.5	5820	0.0015	100	5	140.0	6.5	3.5	3000
00887		1 34.8 1.427		SE1-10-24-4	MONARCH	82H145E13	1957	M	CT	5	168.2	27.4	9.1	12	9150	0.0012	110	5.5	160.0	7	3.2	3000
61555E		1 3.8 28.34		SW6-10-23-4	MONARCH	82H145E13	1996	M	WG	3	170.0	52.0	12.4	13	9150	0.0012	110	5.5	160.0	7	3.2	3000
61555W		1 3.8 27.99		SW6-10-23-4	MONARCH	82H145E13	1996	M	WG	3	170.0	52.0	12.4	13	9150	0.0012	110	5.5	160.0	7	3.2	3000
78065		1 509 2.47.668		NW24-9-23-4	COALHURST	82H18NW41	1985	M	WG	3	162.0	50.0	9.0	11	12630	0.0012	130	6	180.0	8	3.6	4500
79126		1 L		SE25-8-22-4		82H18NW26	UNKNCN				0.0				16980	0.0011						
77527E		1 L		SW36-8-22-4	LETHBRIDGE	82H18NW29	1975	M	WG	6	275.0	37.5	11.0		16990	0.0009	130	7	190.0	9	3.4	5000
77527W		1 L		SW36-8-22-4	LETHBRIDGE	82H18NW29	1984	M	WG	6	275.0	37.5	10.5		16990	0.0009	130	7	190.0	9	3.4	5000
01074		1 3.9 2.189		NW19-9-22-4	LETHBRIDGE	82H18NW29	1946	M	RG, WG	8	241.6	24.5	19.2	14	17050	0.0009	130	7	190.0	9	3.4	5000
72195		1 L		SW5-10-21-4		82H15SW14	UNKNCN				0.0				17080	0.0011						
02210		1 L		NE9-10-21-4		82H15SW31	UNKNCN				0.0				17150	0.0011						
07388		1 845.4 14.353		NE27-10-20-4	NOLAN BRIDGE	82H15SE45	1979	M	WG	4	230.0	50.0	9.1	20	17760	0.0009	140	7.5	200.0	8.5	3.2	5000
78395		1 845.4 14.151		NE27-10-20-4		82H15SE45	UNKNCN				0.0				17760	0.0011						
06986		1 L		NE31-10-18-4		82H16SW43	UNKNCN				0.0				23820	0.0007						

File 01074 – Oldman River at Lethbridge.
Hydrotechnical File History

1899 Existing timber truss on stone filled timber crib substructure.
1900 Piers repaired.
1902 May flood damages bridge; one span washed away completely. June floods 0.91m higher than May and causes more damage.
1903 Bridge reconstructed: 4-33.3m steel through truss and 2-24.4m steel pony truss on concrete substructure 0.9m above streambed.
1908 High water washed out the east approach. Hwm 0.15m below the deck.
1909 Scour hole in front of the east abutment filled with rock.
1942 To stop serious bank erosion a timber and concrete retaining wall and stream diversion are constructed.
1946 Calculations: 1908 hwm 828.33m and 1942 hwm 824.79m.
1948 Bridge reconstructed: 6-32m and 2-24.4m steel girder spans on concrete substructure.
1952 Concrete protection wall constructed at the base of the south abutment.
1953 Hwm 4.2m below the extreme outside corner of the safe wall expansion plate. West abutment eroded. The top of the dike is raised to 1.2m above the high water level.
1954 Concrete bank protection with sandbag riprap is constructed upstream of the bridge
1964 Drift removed from piers.
1966 Bridge widened an additional 13.4m to 20.1m free lanes with median and two sidewalks. Existing substructure lengthened downstream. 13.7m above streambed. Concrete slope protection.
1975 Hwm
1988 Hwm 827.04m
1995 High water. 0.9m deep scour hole developed under the west pier.



Flood Docs for File : 01074 - OLDMAN RIVER

File	Year
01074	1902
01074	1908
01074	1923
01074	1942
01074	1953
01074	1964
01074	1972
01074	1975
01074	1995
01074	2005

Show Flood Document

File 12001
August 16, 1988

NOTE TO FILE

Re: Oals Creek – Hwy. 3 – East of Elkmere
SE8 17-7-5-W-5 0.5-0.5-0.5 (precast Type-MC)

Highwater Inspection – July 12, 1988 14:30 hrs

Water Level at time of Inspection:
4.3 m below top of curb at midbridge (u/s)

Highwater Marks: 1.5 m below top of curb at east abut. (d/s)
1.2 m below top of curb at east abut. (u/s)
1.7 m below top of curb at west abut. (u/s)

Notes: - Streambed; 6.4 m below top of curb at midbridge (u/s)
- Curb height = 0.27 m
- Minor erosion of both headslopes.

Gordon Deenig
Bridge Planning Engineer

AT Records:

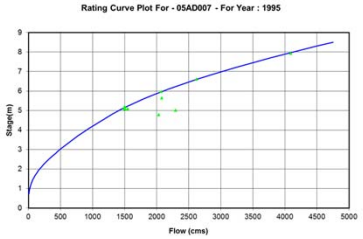
- Access in HIS
- Flood records and file histories
- > 4000 event-site combinations – flood records
- Photos, measurements
- Look u/s and d/s for more coverage

Bridge Design – How Much Water?

Historic Highwater - WSC

11 Records Returned | Show Flows | Sort

Gauge	Description	DA (km²)	# Qi	# Qmd
05AA001	OLDMAN RIVER NEAR COWLEY	1940	0	30
05AA021	OLDMAN RIVER AT THE GAP	1200	0	6
05AA023	OLDMAN RIVER NEAR WALDRON'S CORNER	1446	53	57
05AA024	OLDMAN RIVER NEAR BROCKET	4401	38	40
05AA032	OLDMAN RESERVOIR NEAR PINCHER CREEK	4375		
05AB007	OLDMAN RIVER NEAR FORT MACLEOD	5760	3	39
05AB012	OLDMAN RIVER AT CANAL INTAKE	5590		
05AD007	OLDMAN RIVER NEAR LETHBRIDGE	17031	48	88
05AD019	OLDMAN RIVER NEAR MONARCH	8880	0	22
05AG006	OLDMAN RIVER NEAR THE MOUTH	27533	22	29
07AD006	OLDMAN CREEK NEAR HINTON	18.1	2	3



39 Flow records found for Gauge : 05AB007

Year	Qi (cms)	Qi Date	Qi Time	Qmd (cms)	Qmd Date
1923				1990	06--01
1948				1100	06--18
1942				1060	05--12
1929				671	06--04
1916				609	06--21
1934				541	06--08
1927				493	06--12
1911				467	05--16
1938				445	05--26
1945				411	06--07
1928				394	07--01
1937				391	06--13

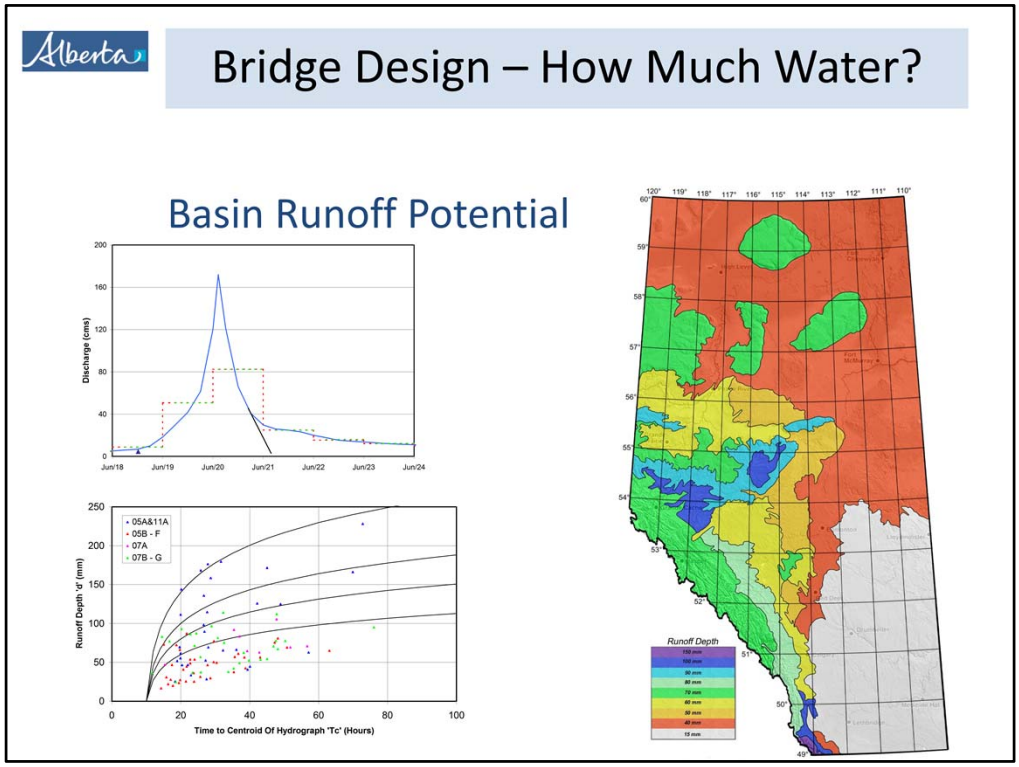
Highest Gaugings

Date	Flow (cms)	Stage (m)	Top Width (m)	Flow Area (sq. m)
June 8, 1995	4090.0	7.93	232.0	1570.0
June 9, 1995	2620.0	6.60	226.0	1210.0
June 2, 1923	2293.7	5.01	231.0	880.7
June 10, 1964	2078.5	5.64	223.4	975.5
June 22, 1975	2070.0	5.96	209.1	975.5
June 3, 1923	2033.1	4.79	231.0	843.4
June 23, 1975	1546.1	5.08	203.3	812.0
June 11, 1953	1500.5	5.20	233.8	1161.3
June 10, 1995	1500.0	5.14	203.0	829.0
June 8, 2005	1498.7	5.07	202.8	714.1
June 9, 1964	1333.7	4.78	217.9	728.4
June 10, 2005	1282.2	4.57	192.0	622.7
June 6, 1923	1132.7	3.68	196.6	577.1

Year	Month	Runoff Depth (mm)	Time to Peak (hr)	Time of Base (hr)	Qbase (cms)	Qrise (cms)
1995	6	35	34	84	477	4193
1975	6	29	62	138	587	2233
1923	6	27	54	111	265	2565
1942	6	26	58	116	305	2405
1964	6	26	65	148	483	1721
1953	6	21	55	110	1154	1956
2005	6	21	55	107	468	2082
1991	6	15	58	136	102	892
1928	7	15	53	126	333	907
1948	6	14	28	64	1216	2284
1948	5	13	46	96	597	1636
1942	6	11	53	120	245	884
1937	6	10	52	116	386	838
1963	7	10	58	125	171	732
1929	6	10	64	128	390	790

WSC Records:

- ~1000 sites, ~ 400 active at any time
- AT got access to raw data in addition to published, built tool to access and display
- Provide published max mean daily Q, highest gaugings, processed hydrographs, and rating curve plots showing actuals

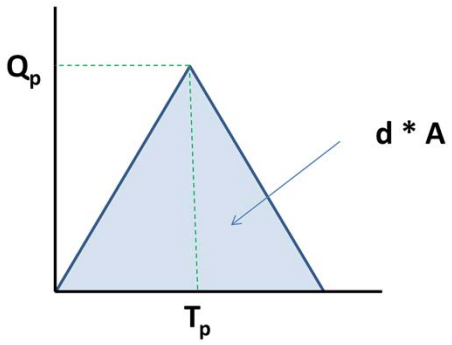


Basin Runoff Potential

- Upper bound check – ability of basin to supply water if routing was not a constraint
- Analysis of >3000 runoff events at WSC gauges
- Geographic assignment based on envelope curves for distinct hydrologic districts
- Map created for design use

Bridge Design – How Much Water?

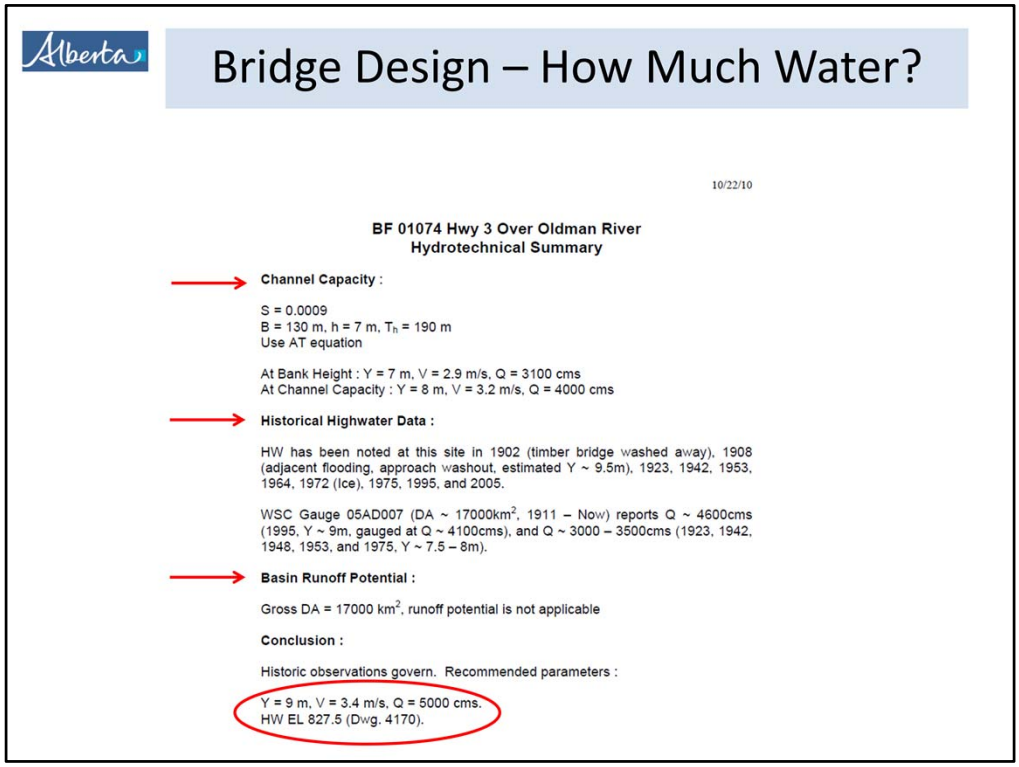
Basin Runoff Potential



Application:

- Derive drainage area through GIS/DEM
- Set Tp = 20 hrs (conservative)
- Determine unit discharge ‘q’ from ‘d’
- Classic case :
    - Tributary to large stream
    - Small DA (km2)
    - End of channel steep and deep (ravine) – lots of capacity
    - Not enough water to fill it

Bridge Design – How Much Water?



10/22/10

BF 01074 Hwy 3 Over Oldman River
Hydrotechnical Summary

Channel Capacity :

S = 0.0009
B = 130 m, h = 7 m, T_h = 190 m
Use AT equation

At Bank Height : Y = 7 m, V = 2.9 m/s, Q = 3100 cms
At Channel Capacity : Y = 8 m, V = 3.2 m/s, Q = 4000 cms

Historical Highwater Data :

HW has been noted at this site in 1902 (timber bridge washed away), 1908 (adjacent flooding, approach washout, estimated Y ~ 9.5m), 1923, 1942, 1953, 1964, 1972 (Ice), 1975, 1995, and 2005.

WSC Gauge 05AD007 (DA ~ 17000km^2, 1911 – Now) reports Q ~ 4600cms (1995, Y ~ 9m, gauged at Q ~ 4100cms), and Q ~ 3000 – 3500cms (1923, 1942, 1948, 1953, and 1975, Y ~ 7.5 – 8m).

Basin Runoff Potential :

Gross DA = 17000 km^2, runoff potential is not applicable

Conclusion :

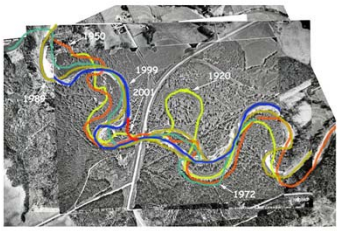
Historic observations govern. Recommended parameters :

Y = 9 m, V = 3.4 m/s, Q = 5000 cms.
HW EL 827.5 (Dwg. 4170).

Putting it all together:

- Hydrotechnical summaries published for >1500 bridges (most of the big ones)
- Combine 3 components to one set of parameters

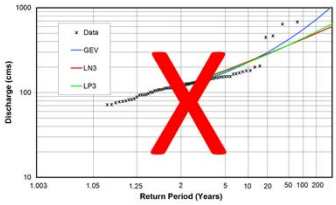
Bridge Design – How Much Water?

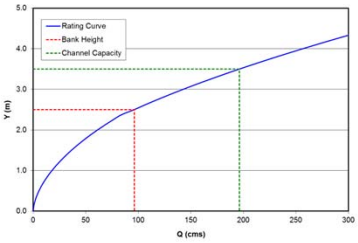


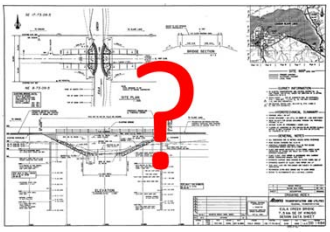
Don’t be too precise:

- Drift
- Ice
- Alignment changes
- Channel changes

Bridge Design – How Much Water?







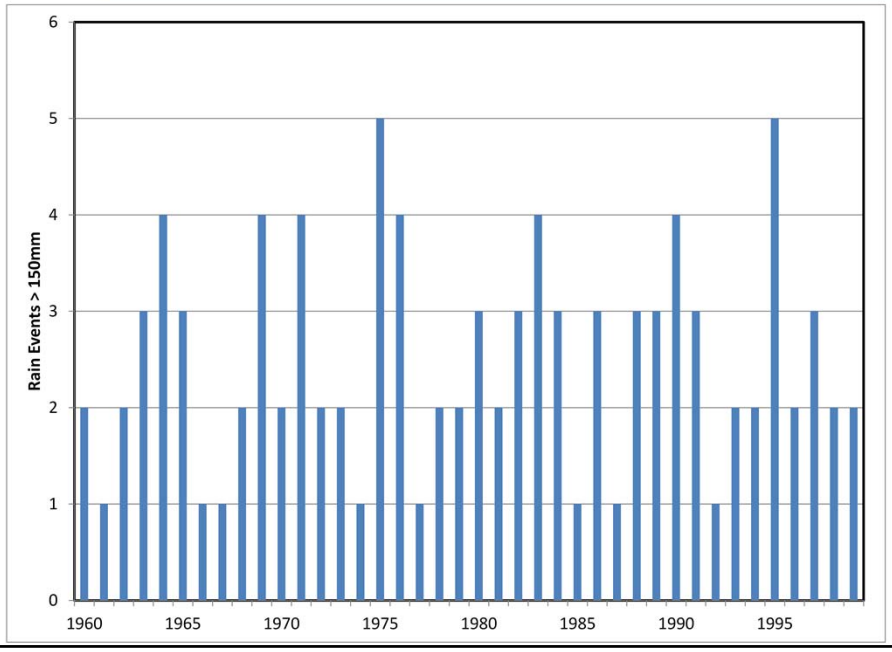
Key Messages:

- It matters
- Should match physics, observations
- HDG
- Boundary condition – how to design for? – another story

Bridge Design – How Much Water?

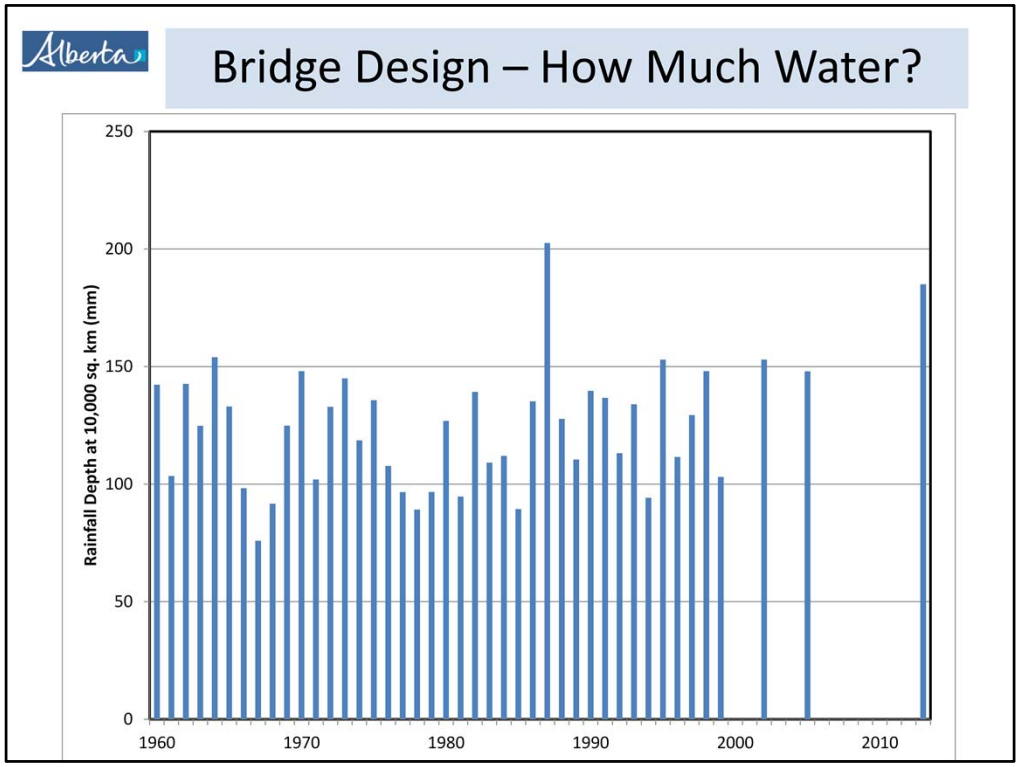
Climate change – flooding and storms more frequent, more intense?

Bridge Design – How Much Water?



Storm frequency:

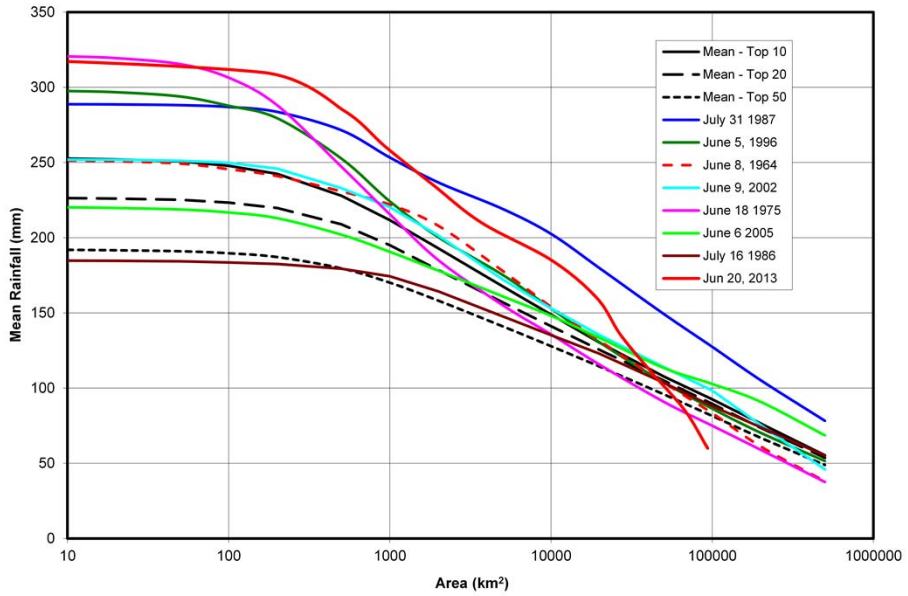
- Rain events with > 150mm reported at multiple gauges
- 1960 – 2000 – relatively constant number of gauges
- No observable trend in storm frequency



Storm Magnitude:

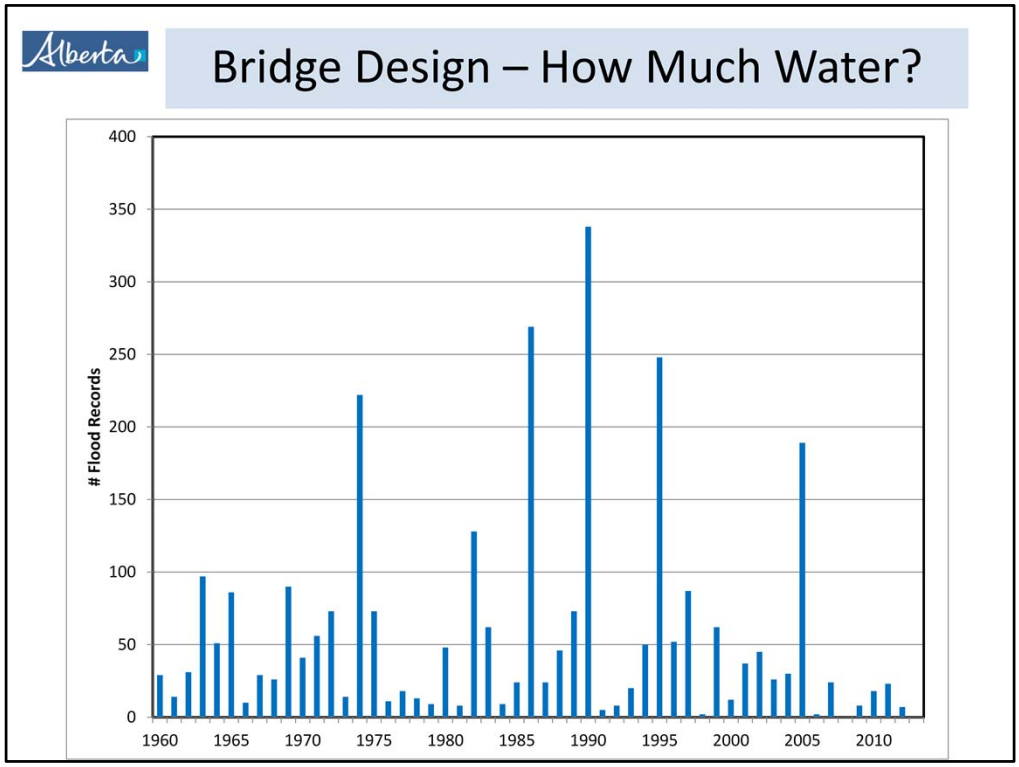
- Depth (mm) covering same area (10,000km2)
- July 31, 1987 is the largest (Tornado storm, over Simonette River)
- Jun 20, 2013 storm second biggest since 1960, but larger runoff prior – 1879, 1987, 1902, 1929, 1932
- No visible trend in rainfall magnitude

Bridge Design – How Much Water?



Storm Magnitude:

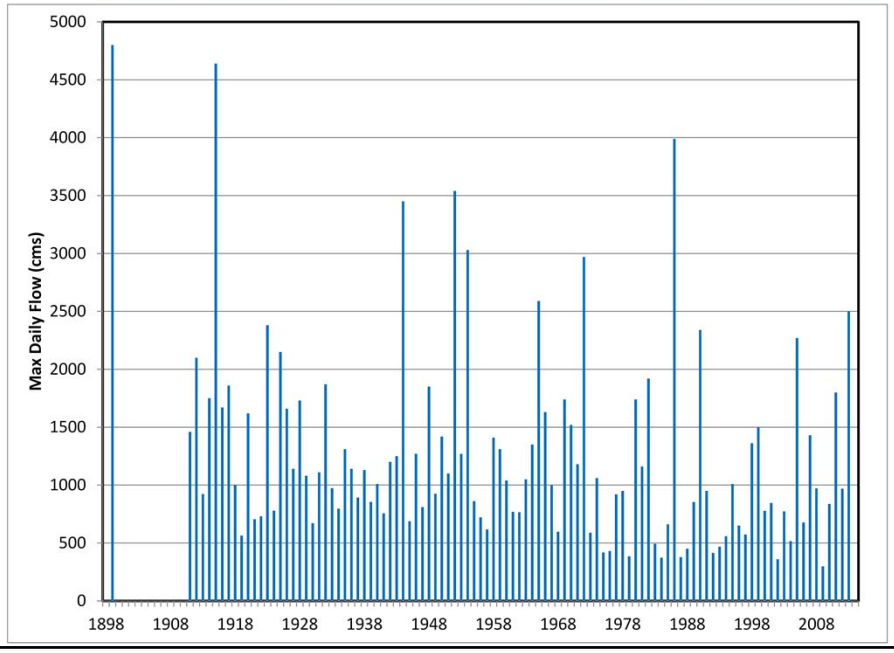
- Depth (mm) vs. Area (km2)
- Red line is prelim June 2013 Storm
- Close to 1975 at eye, close to 1987 at 1000 – 10,000 km2 range
- Definitely big, not completely out of range
- Don’t have good data for late 1800 early 1900 storms, same or more runoff



Flood Frequency:

- ~ 3700 flood records in HIS, back to 1879
- Much fewer structures < 1960
- Something, somewhere every year
- Widest – 1974, 1982, 1986, 1990 (2), 1995, 2005 (2), 2013

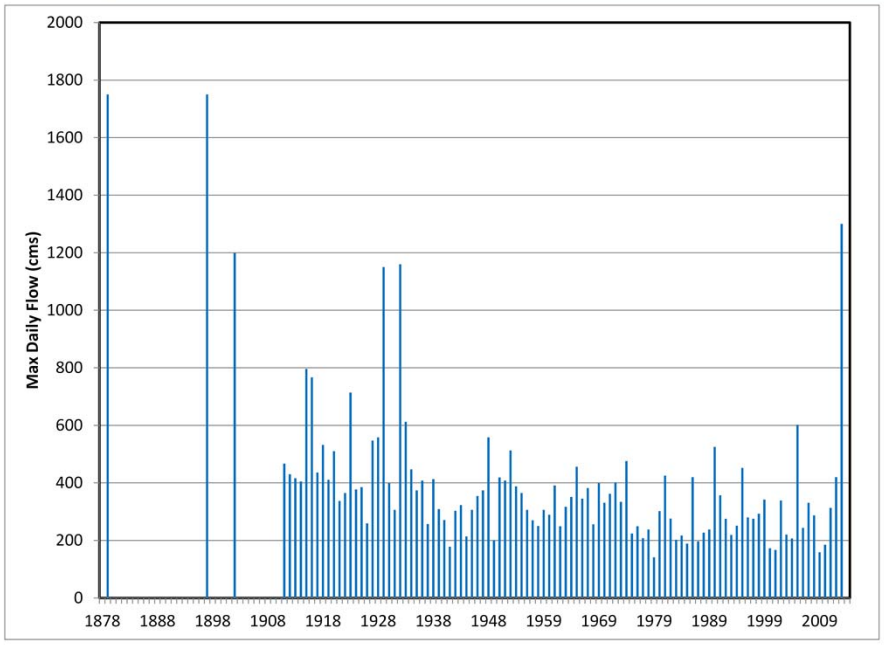
Bridge Design – How Much Water?



Flood Magnitude : WSC Gauge – NSR at Edmonton

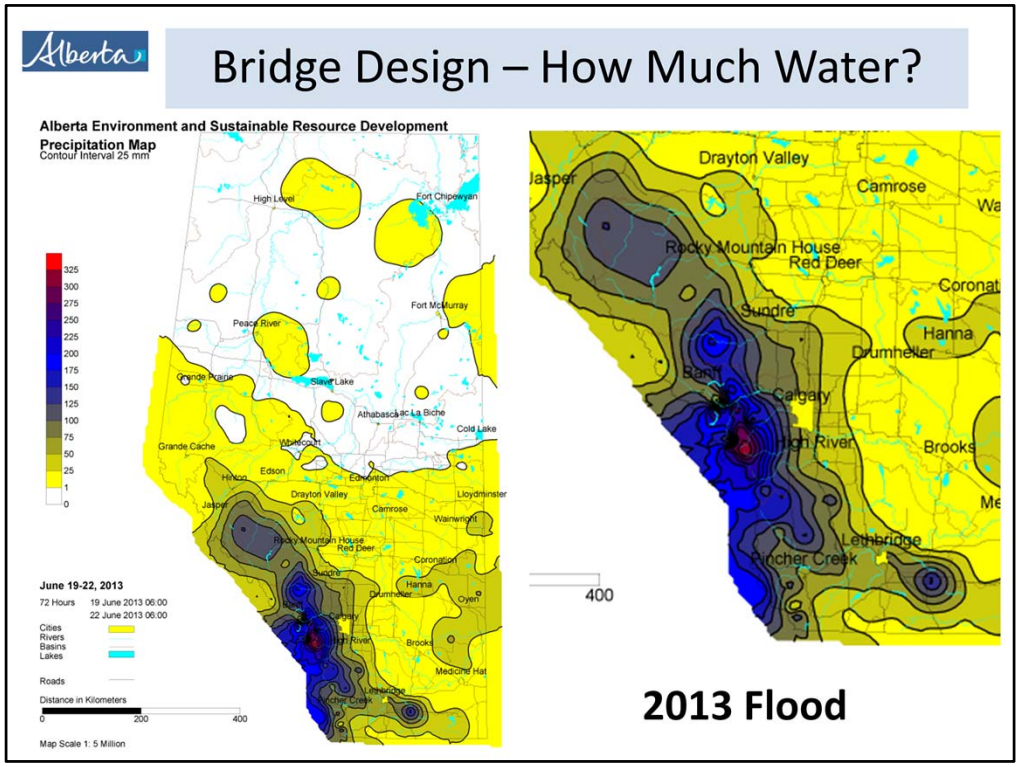
- Long continuous Record
- Historic event recorded in 1899, other peaks in 1915, and 1952
- No visible trend in peaks

Bridge Design – How Much Water?



Flood Magnitude : WSC Gauge – Bow River at Calgary

- Long continuous Record
- Significant floods pre-record in 1879, 1897, and 1902 – photographic evidence, documented in floodplain studies
- No visible trend in peaks
- Long period between large floods (1995 storm was tracking for Bow basin)


Bridge Design – How Much Water?
Alberta Environment and Sustainable Resource Development
Precipitation Map
Contour Interval 25 mm
325
300
275
250
225
200
175
150
125
100
75
50
25
1
0
June 19-22, 2013
72 Hours 19 June 2013 06:00
22 June 2013 06:00
Cities
Rivers
Basins
Lakes
Roads
Distance in Kilometers
0
200
400
Map Scale 1: 5 Million
High Level
Fort Chipewyan
Fort McMurray
Peace River
Grande Prairie
Slave Lake
Athabasca
La Biche
Cold Lake
Grande Cache
Whitecourt
Edson
Hinton
Edmonton
Drayton Valley
Jasper
Lloydminster
Camrose
Wainwright
Rocky Mountain House
Red Deer
Coronation
Sundre
Hanna
Drumheller
Oyen
Calgary
High River
Brooks
Medicine Hat
Lethbridge
Pincher Creek
Drayton Valley
Camrose
Rocky Mountain House
Red Deer
Sundre
Hanna
Drumheller
Banff
Calgary
High River
Brooks
Lethbridge
Pincher Creek
400
2013 Flood

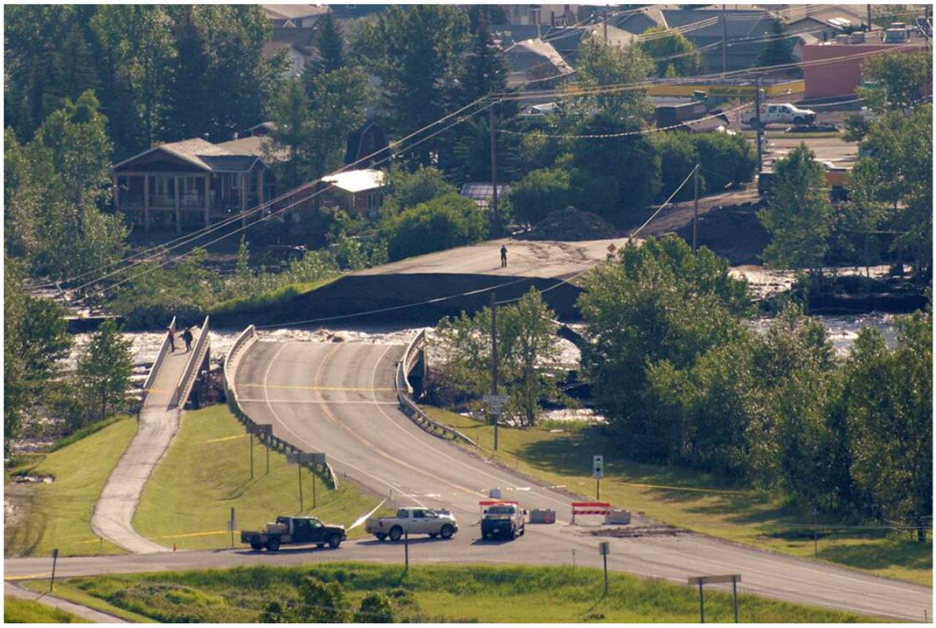
2013 Flood

Bridge Design – How Much Water?

Hwy 40 (and pedestrian trail) over Evan Thomas Ck (south of Kananaskis Golf Course)

- Note drift impact
- Note lateral instability
- Opening OK, RPW not

Bridge Design – How Much Water?



Hwy 22 over Sheep River at Black Diamond

- Bridge OK, road not
- Insufficient RPW u/s right bank, campground

Bridge Design – How Much Water?

Hwy 66 over Elbow River

- Abutment washout and damage
- Seems to be continual slumping, not realignment

Bridge Design – How Much Water?

Hwy 66 over Elbow River

- Note considerable drop in elevation at abutment (~ 4 feet)
- Will need a re-build of at least end span

Highwood River beside Hwy 541

Bridge Design – How Much Water?

Cougar Ck – Hwy 1:

- Crossing alluvial fan
- Note lateral mobility
- Note lack of development
- Post 1974 flood

Bridge Design – How Much Water?

Cougar Ck – Hwy 1:

- Early in May 1990 flood
- Culvert working OK before plugged
- Note V, colour of water

Bridge Design – How Much Water?

Cougar Ck – Hwy 1:

- Crossing alluvial fan
- Debris flow
- Closed for ~ 1 week
- Note - lots of development adjacent to channel

Bridge Design – How Much Water?

Cougar Ck – Hwy 1:

- Crossing alluvial fan
- Debris flow
- Closed for ~ 1 week
- Note - damage, debris on top, trucks

Bridge Design – How Much Water?

Cougar Ck – Hwy 1:

- 1 week later, looking d/s
- Highway now open – restricted speed, lanes
- Difficulty in holding alignment, handling debris