Water Conservation For Mountain Communities

Hans Schreier, UBC, Vancouver, Canada

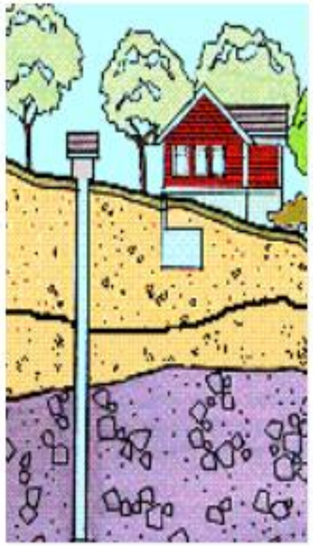
Different Water Sources Need Different Protective Measures

A 4 Step Process:

1. Delineate the Water Source
2. Identify the Potential Sources of Contamination
3. Determine the Suseptibility & Vulnerability
4. Prioritize Risk and Determine Capacity to Mitigate

Rivers & Streams

Groundwater



Springs

Reservoirs and Lakes

Rainwater Harvesting

Options for Dealing with the Uncertainy of Water Supplies in Mountains Communities

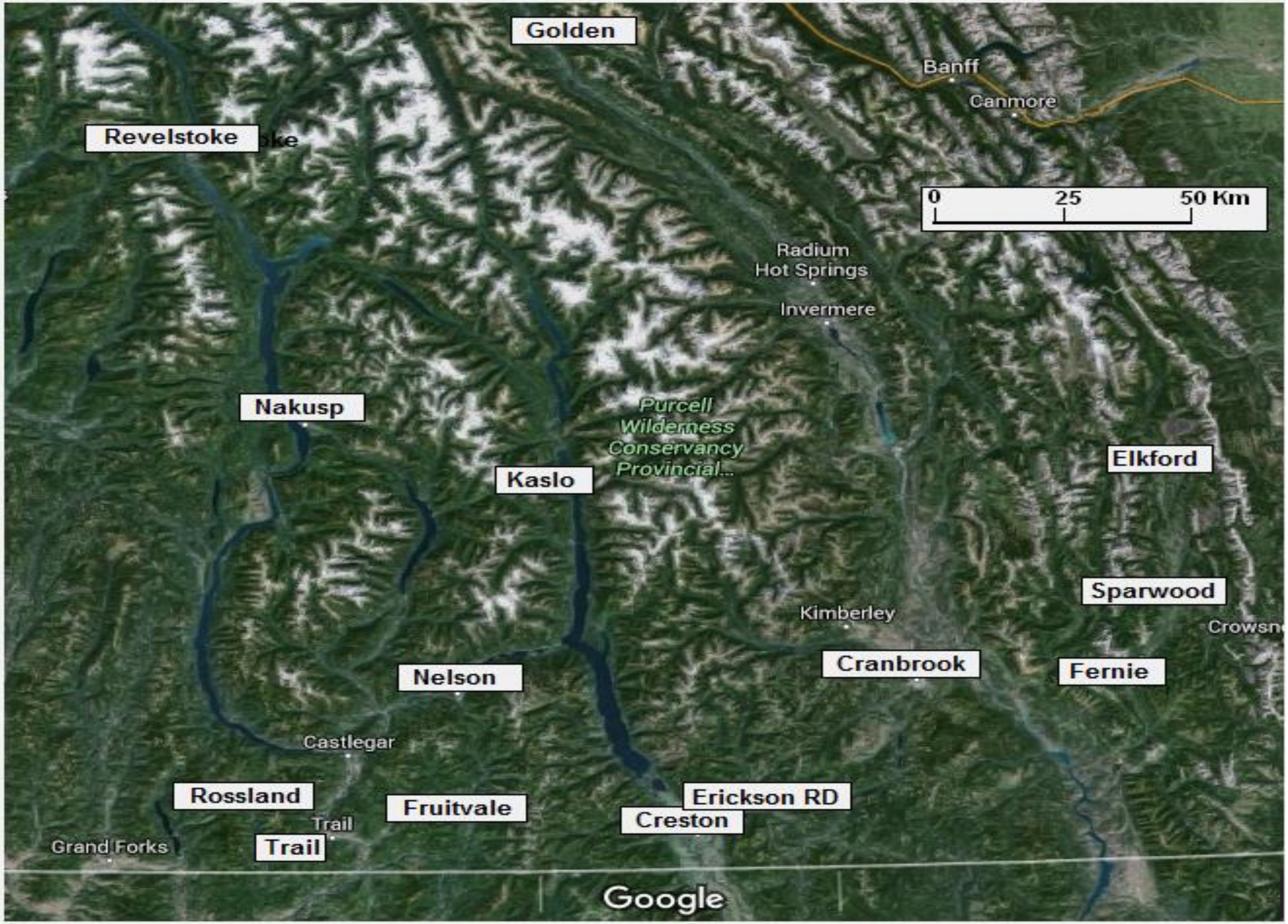
Enhance Storage	Conservation	New Water Sources	Re-Use of Water
Expensive	Most Cost Effective Short Term Option	Difficult	Restricted Use Unless Treatment

Water Consumption in Mountain Communities in the Columbia Basin in Canada

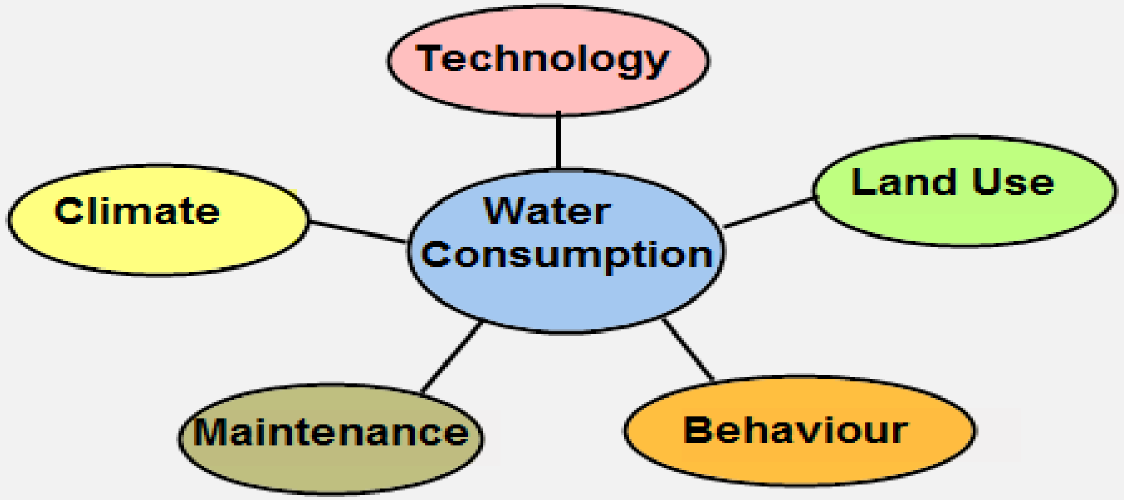
Based on a Reconaissance Survey in 2005 it was noted that Mountain Communities in the Columbia Basin use very large amounts of water but this was based on very unreliable data

- The Columbia Basin Trust (CBT) Initiated the Water-Smart Conservation Program in 2009
- 20 Communities Participated in the Program and pledged to reduce their Water Consumption by 20% between 2009 and 2015
- 14 Communities had comparable data
- 12 Climate Stations were used to compare conservation results

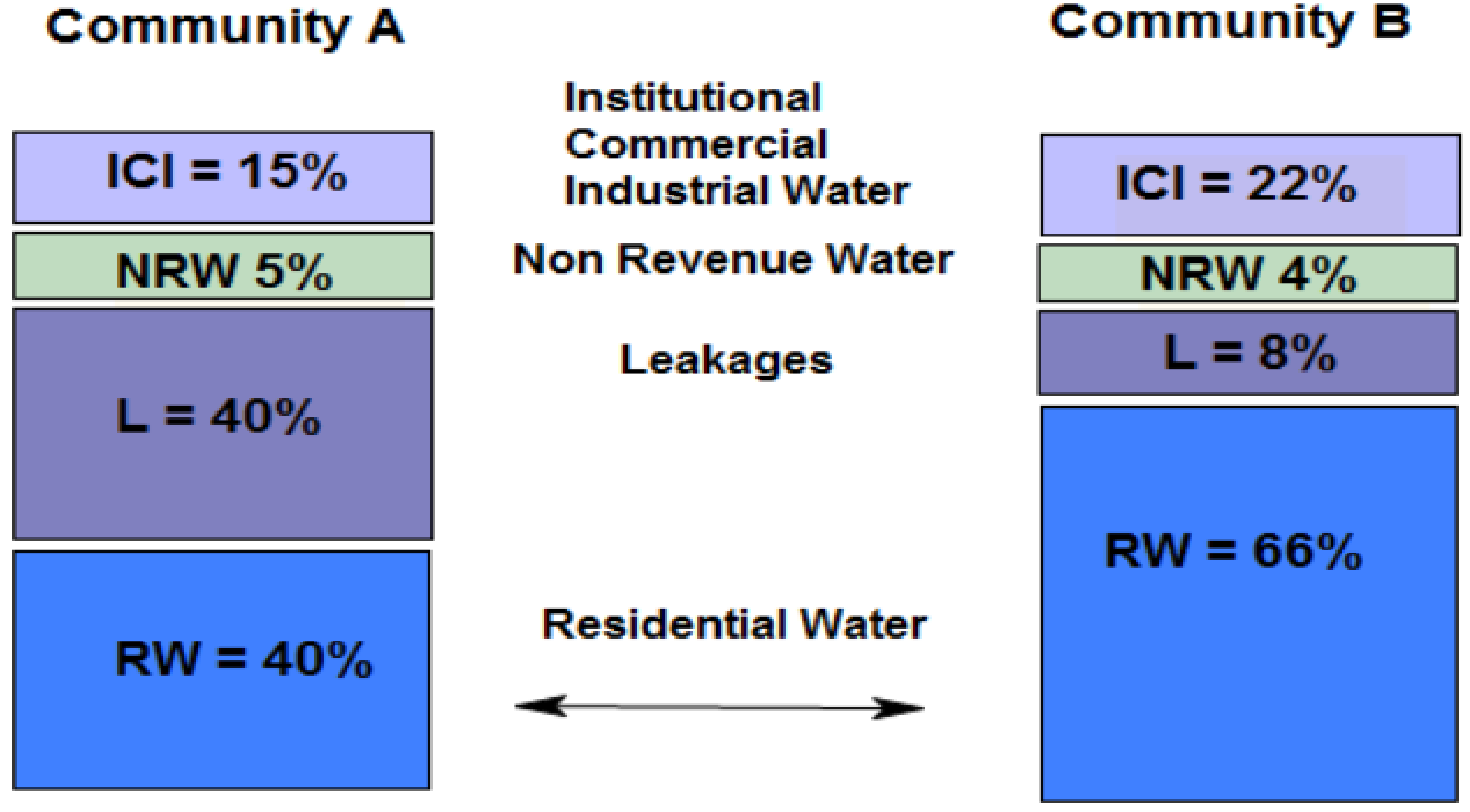
14 Participating Communities



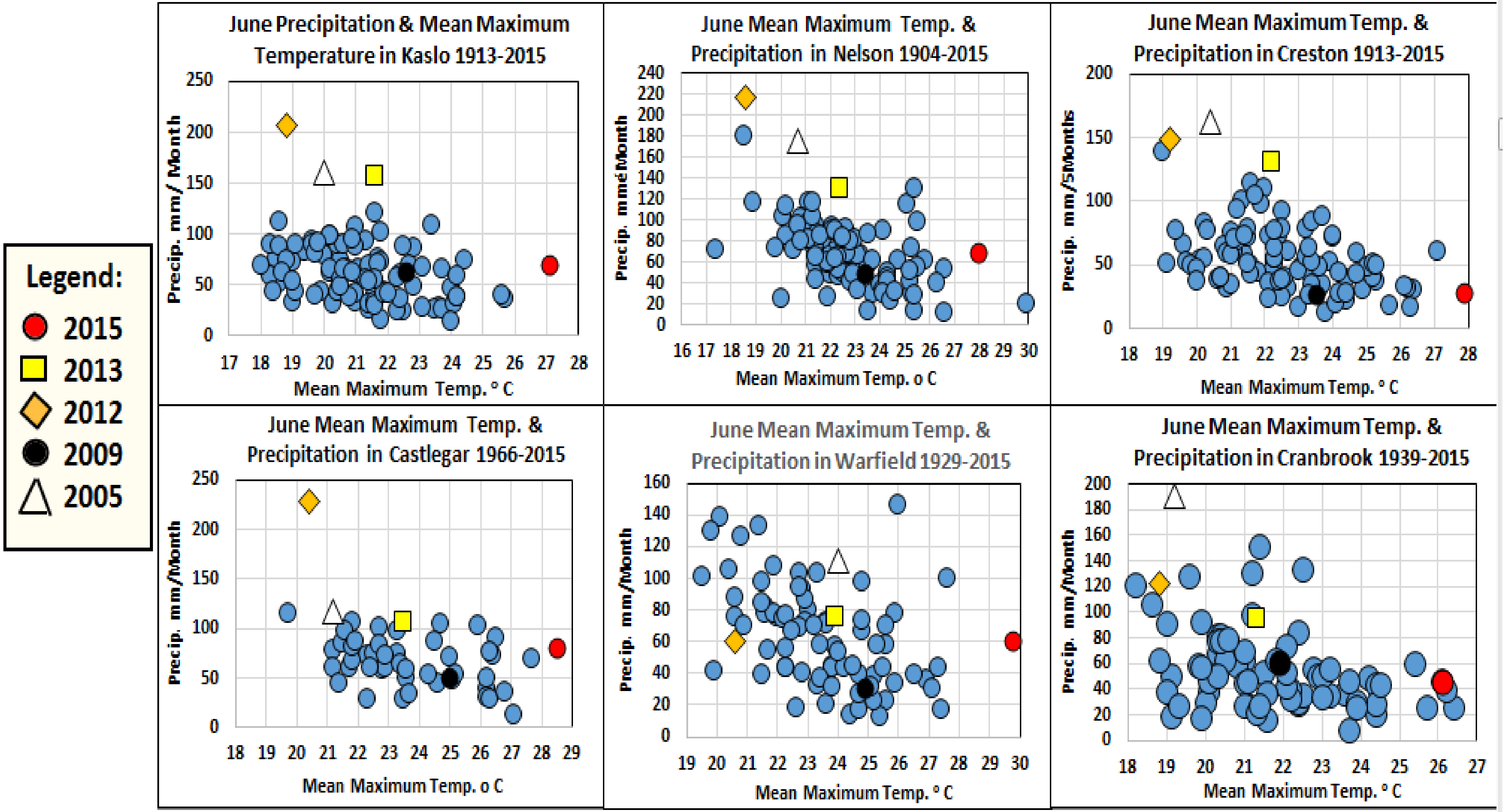
Key Factors that Influence Domestic Water Consumption & Use	
Factors	**Details**
Climate	Temperature & Precipitation
Land Use	Indoor vs. Outdoor Use, Commercial & Industrial
Human Behaviour	Beliefs, Habits, Incentives & Regulations
Management	Capacity & Skills to Maintain Infrastructure
Technology	Type of Infrastructure, Quality, Longevity



Water Use Differs in each Community due to Technical Factors, Type of Use Behaviour and Climatic Conditions

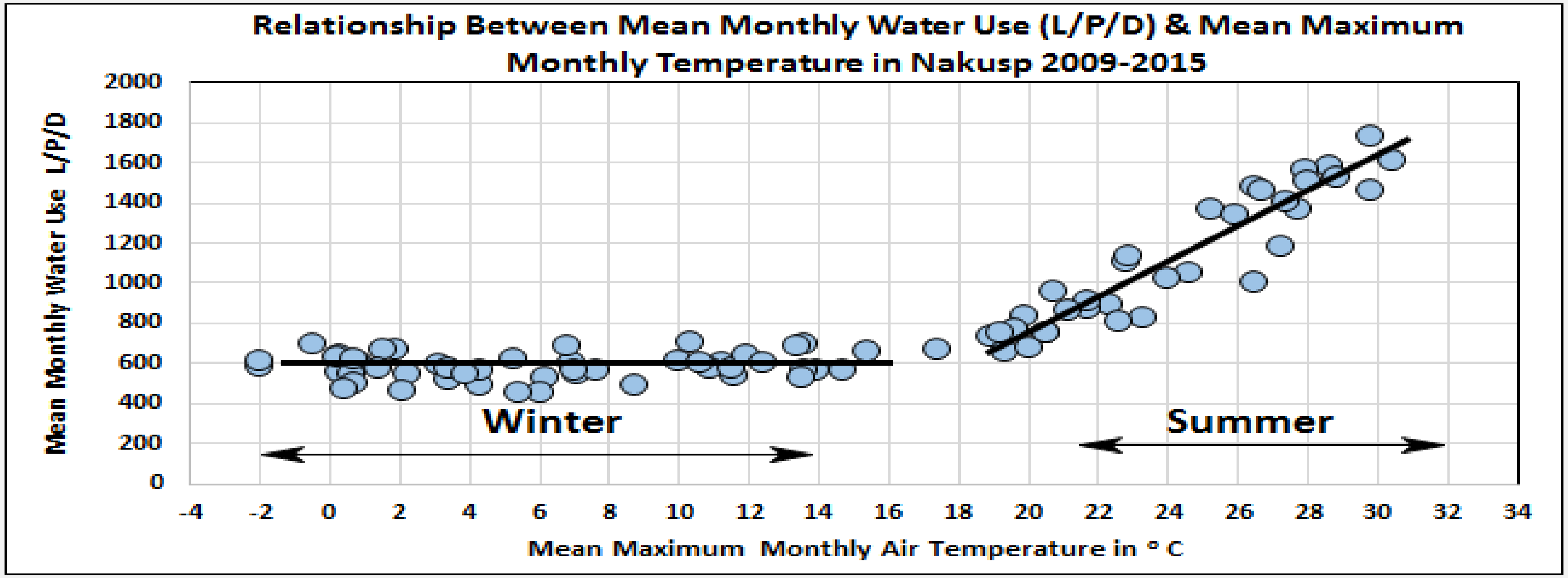


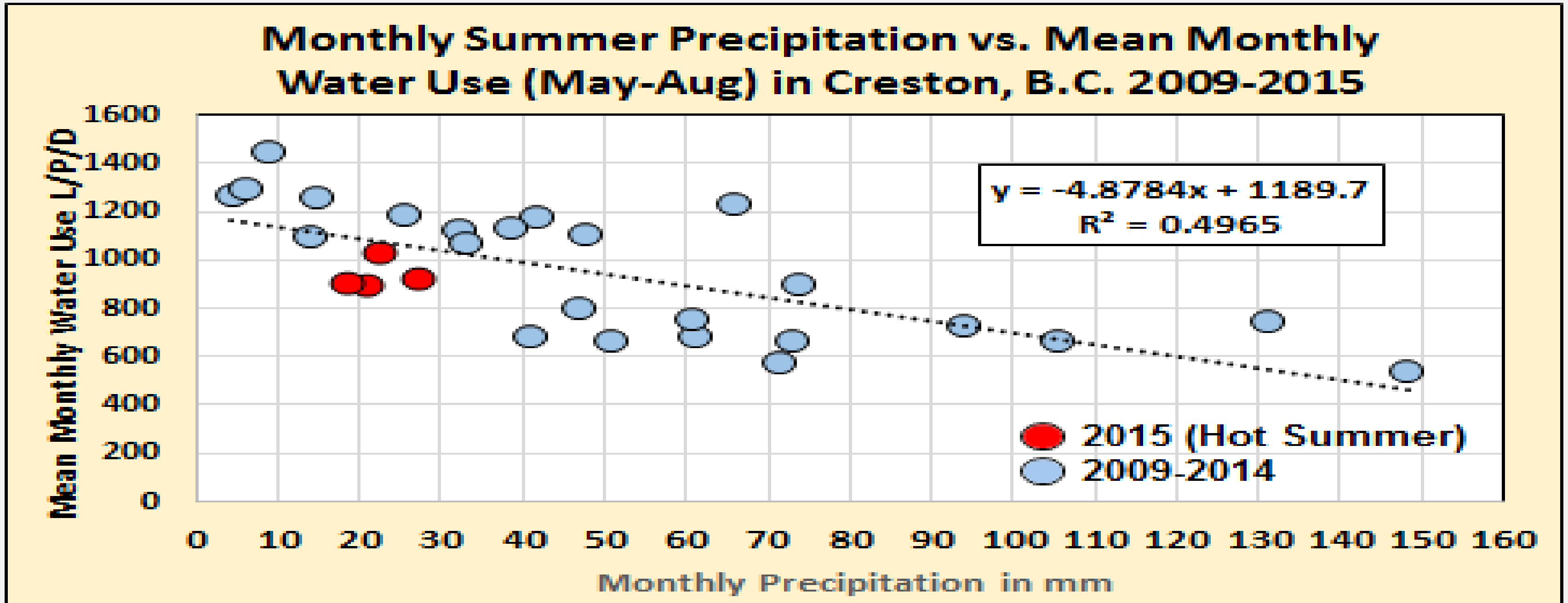
June Temperature & Precipitation Changes over Historic Records

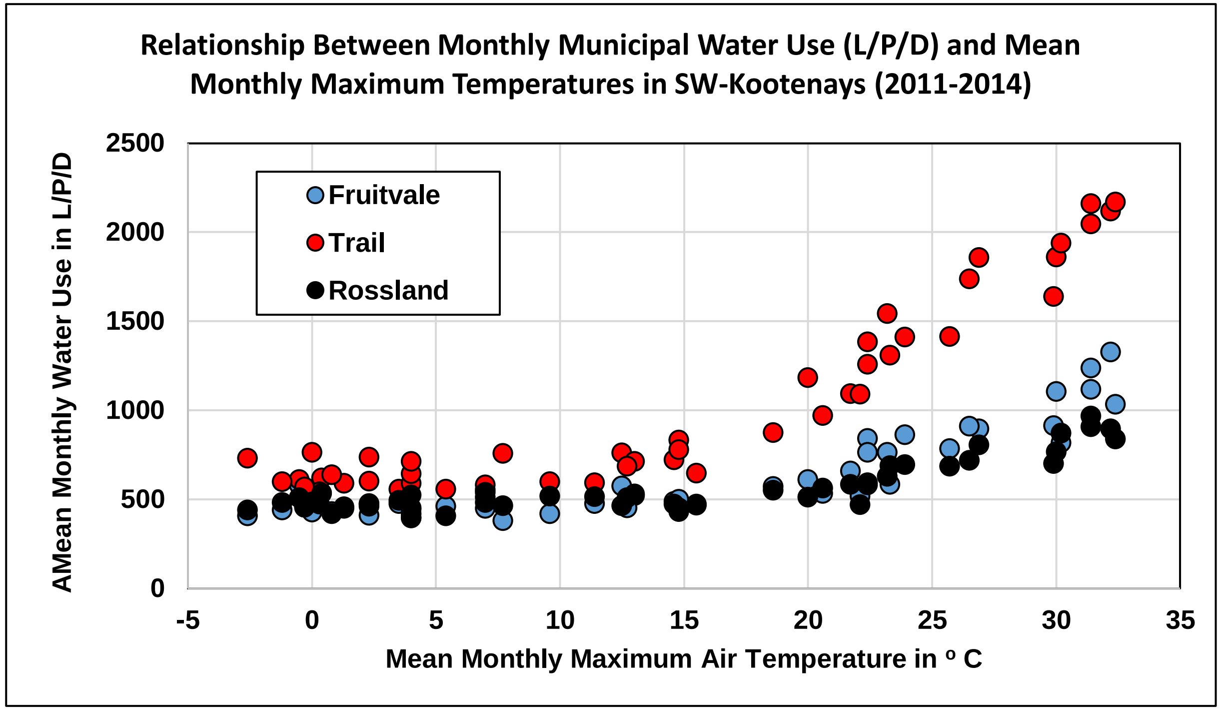


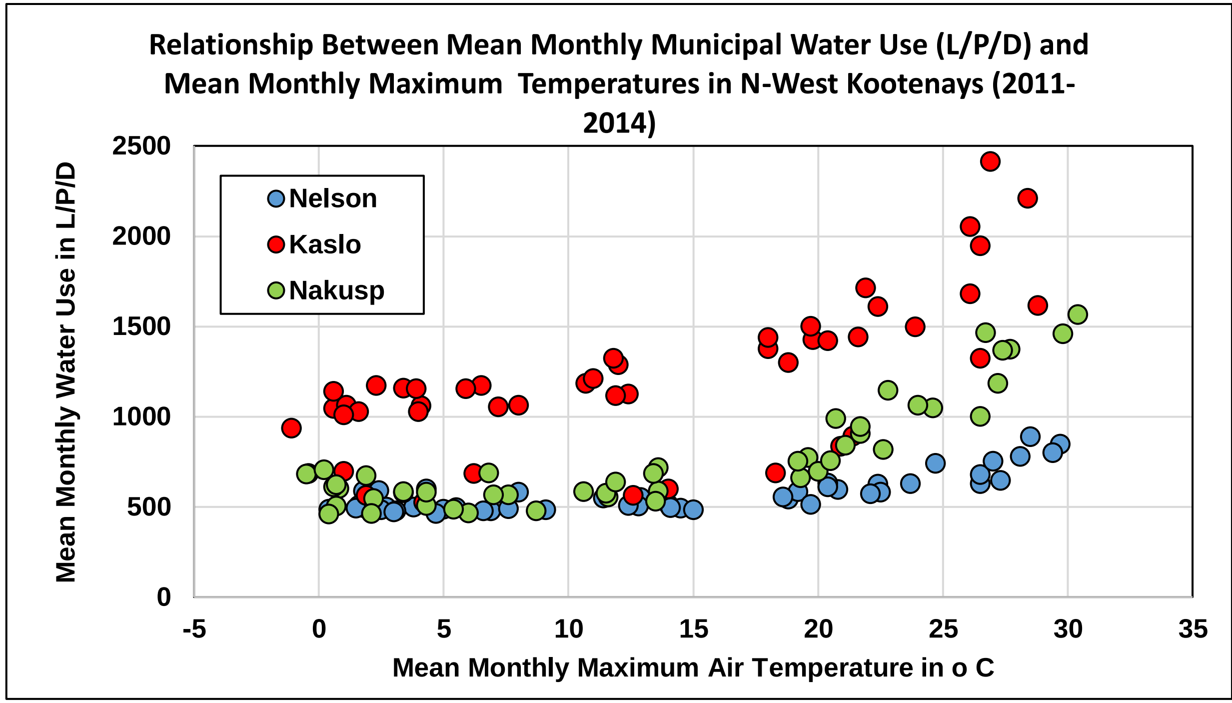
Temperature Impact on Water Consumption During Winter & Summer

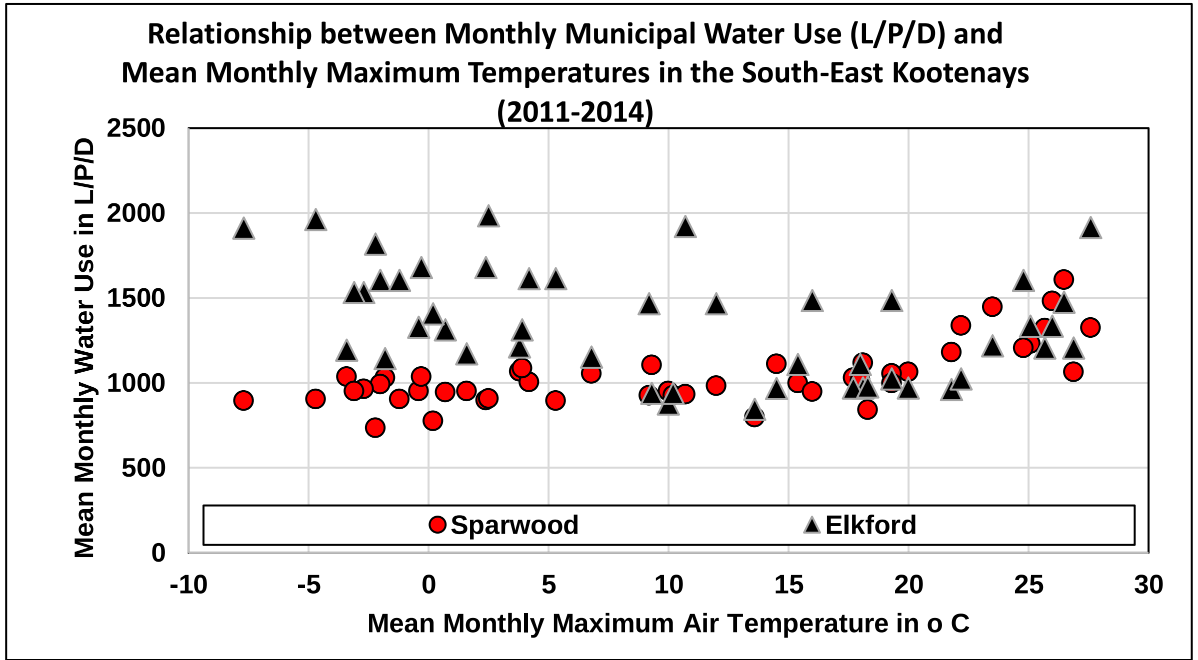
Based on 7 Year Data 2009-2015 & Mean Maximum Monthly Air Temperatures

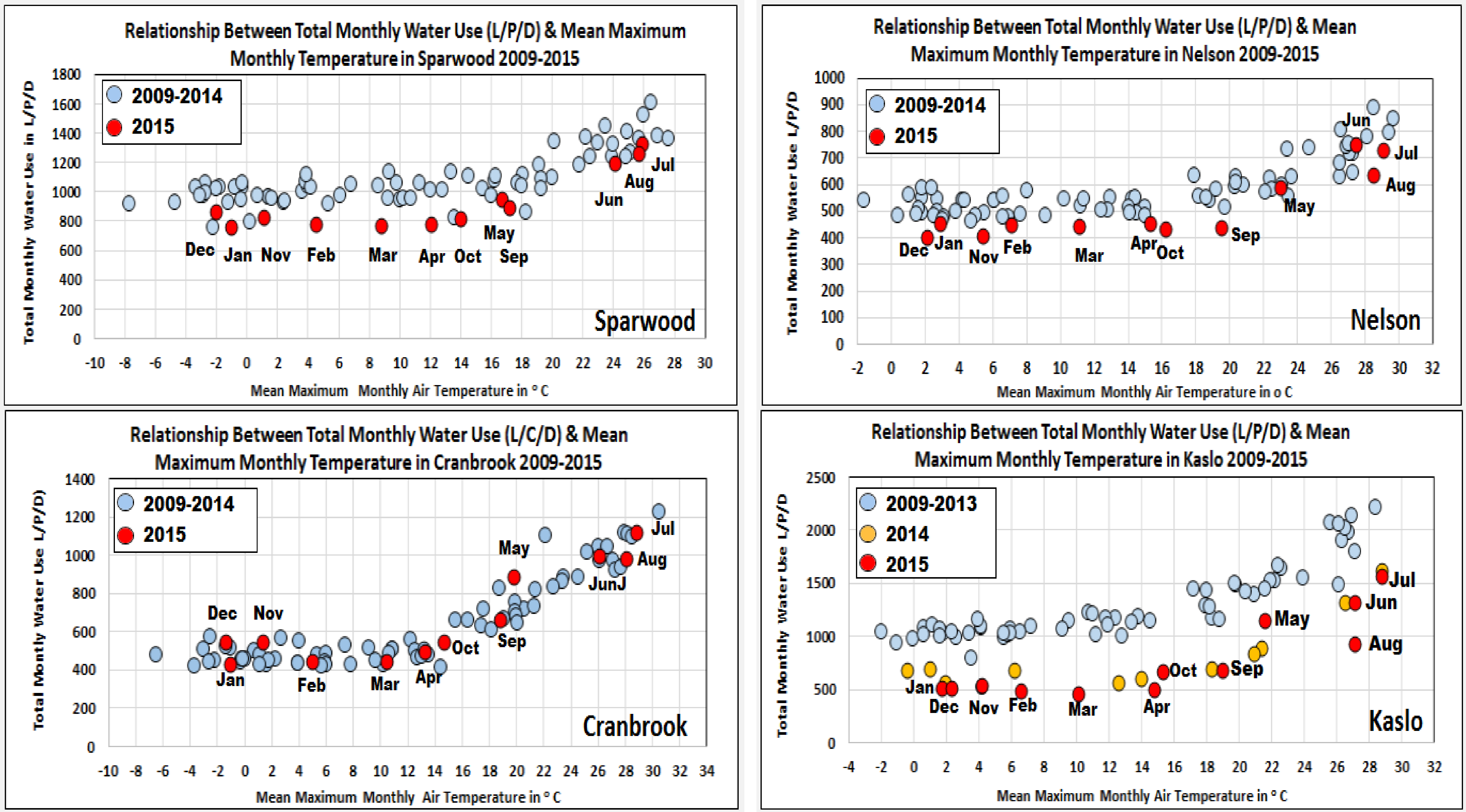




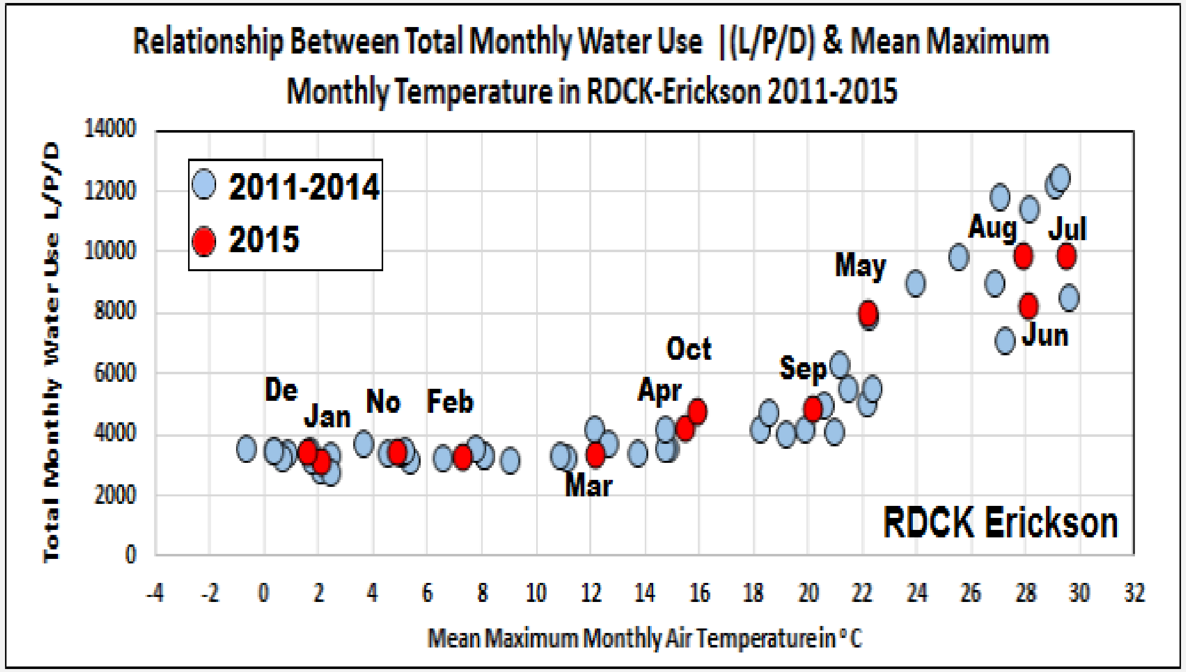

Relationship Between Monthly Municipal Water Use (L/P/D) and Mean Monthly Maximum Temperatures in SW-Kootenays (2011-2014)
AMean Monthly Water Use in L/P/D
Mean Monthly Maximum Air Temperature in º C
Fruitvale
Trail
Rossland

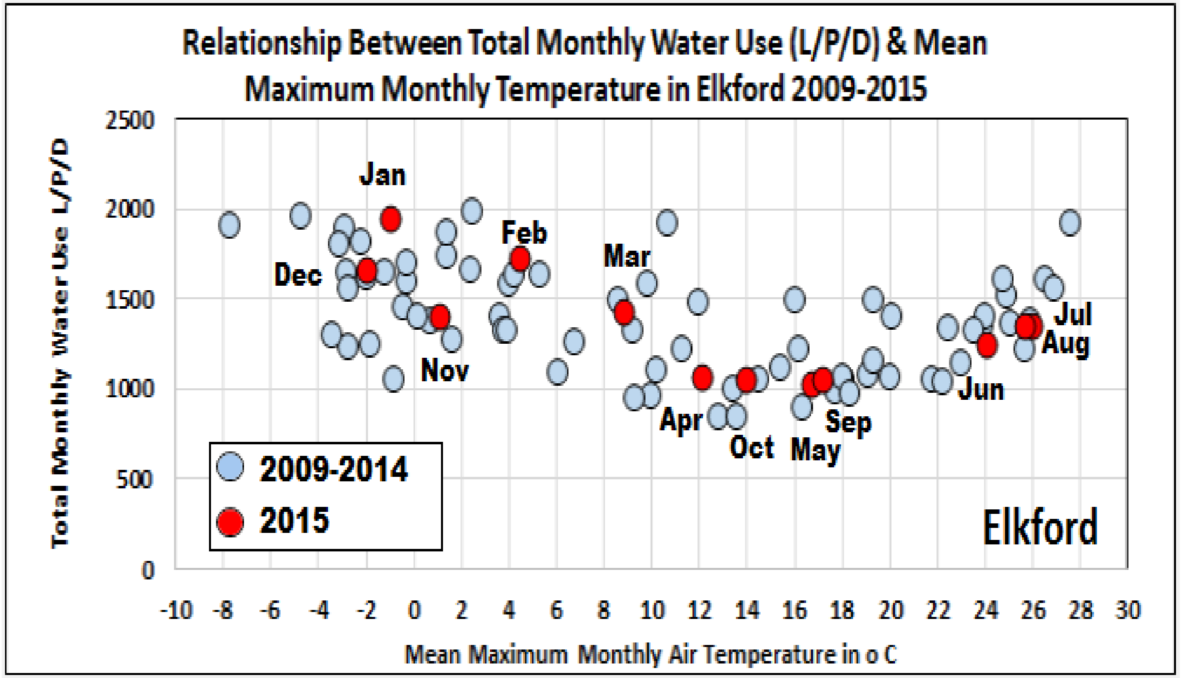

Relationship Between Mean Monthly Municipal Water Use (L/P/D) and Mean Monthly Maximum Temperatures in N-West Kootenays (2011-2014)
Mean Monthly Water Use in L/P/D
Mean Monthly Maximum Air Temperature in o C
Nelson
Kaslo
Nakusp

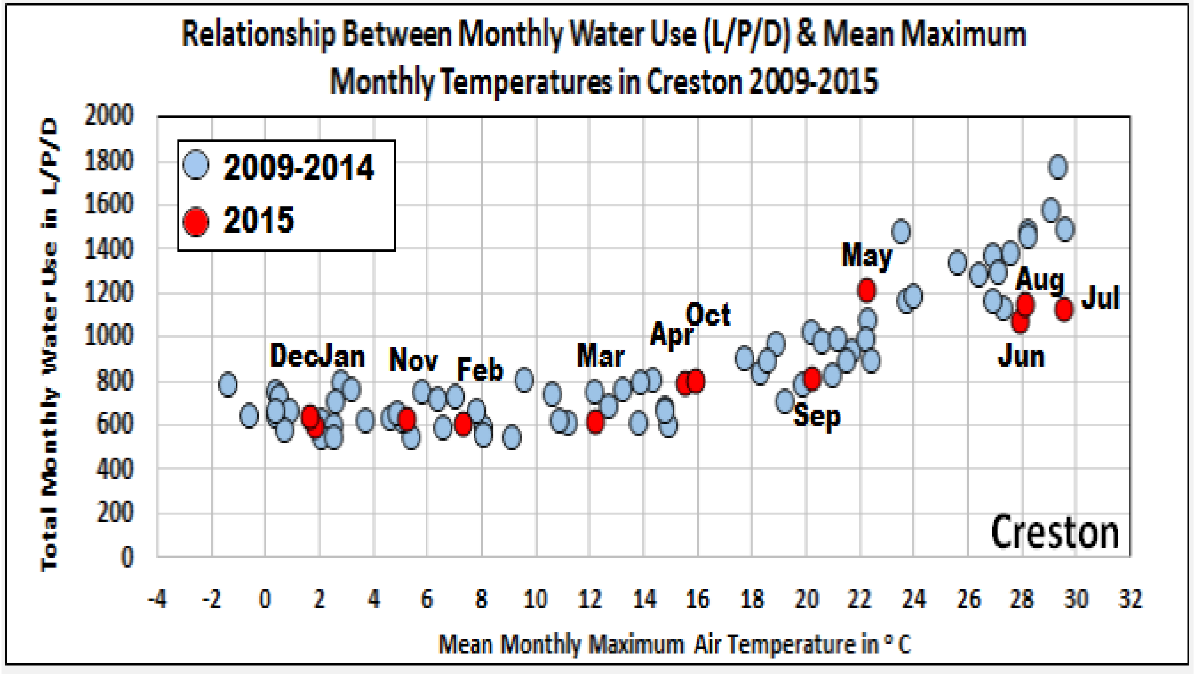

Relationship between Monthly Municipal Water Use (L/P/D) and Mean Monthly Maximum Temperatures in the South-East Kootenays (2011-2014)
Mean Monthly Water Use in L/P/D
Mean Monthly Maximum Air Temperature in o C
Sparwood
Elkford

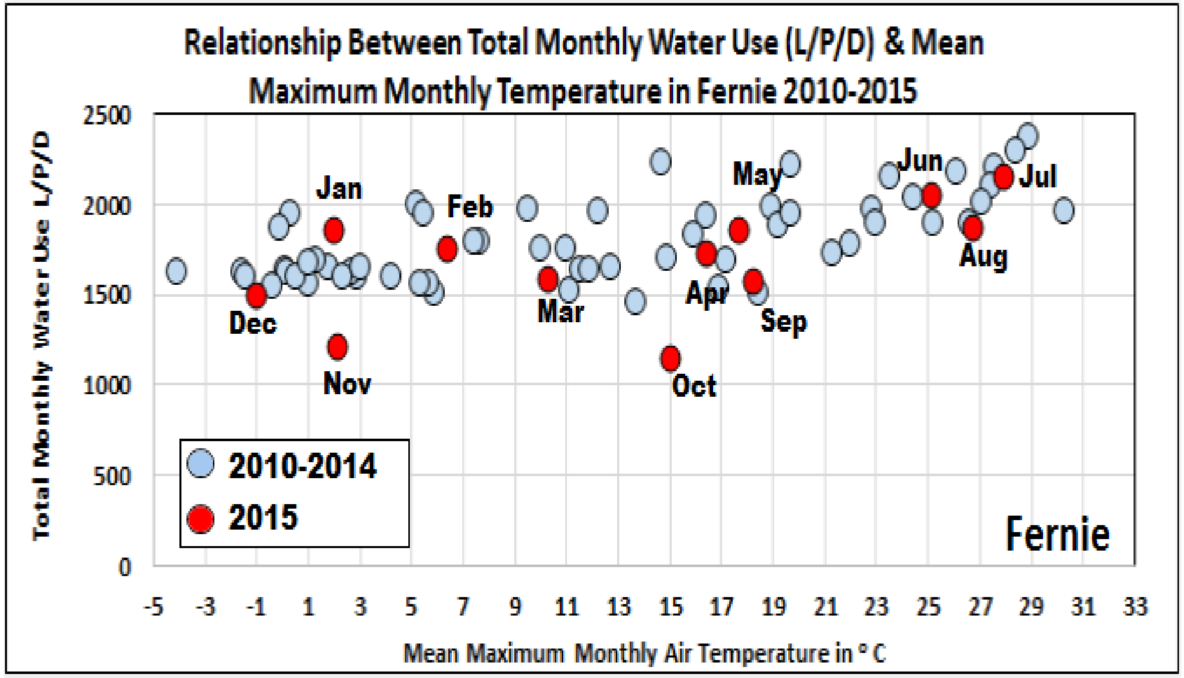


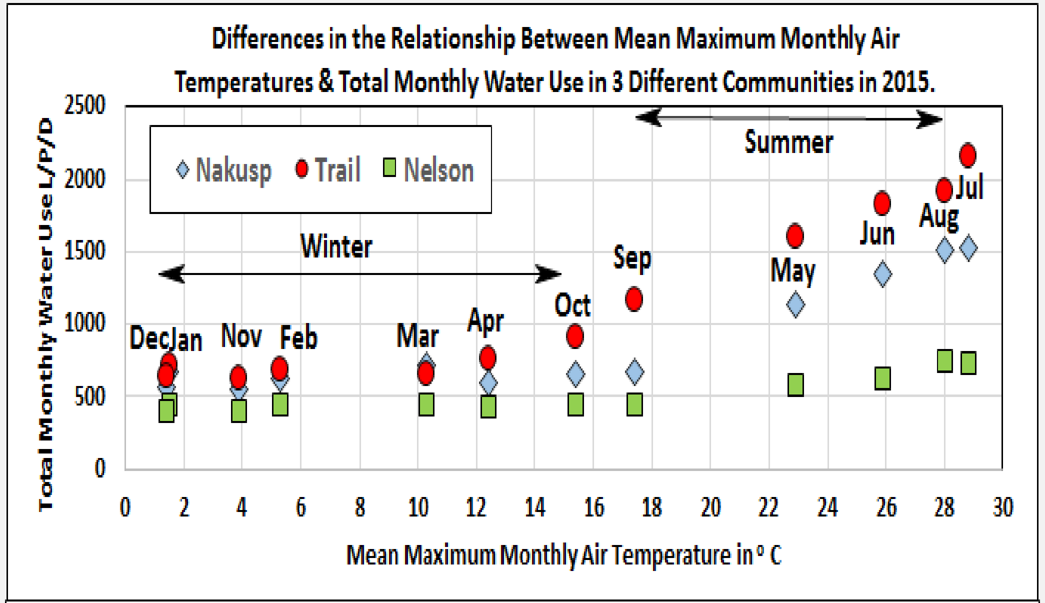
Relationship Between Total Monthly Water Use (L/P/D) & Mean Maximum Monthly Temperature in Sparwood 2009-2015
Total Monthly Water Use in L/P/D
Mean Maximum Monthly Air Temperature in ° C
2009-2014
2015
Sparwood
Dec
Jan
Nov
Feb
Mar
Apr
Oct
May
Sep
Jun
Aug
Jul
Relationship Between Total Monthly Water Use (L/P/D) & Mean Maximum Monthly Temperature in Nelson 2009-2015
Total Monthly Water Use L/P/D
Mean Maximum Monthly Air Temperature in o C
Nelson
Relationship Between Total Monthly Water Use (L/C/D) & Mean Maximum Monthly Temperature in Cranbrook 2009-2015
Total Montly Water Use L/P/D)
Mean Maximum Monthly Air Temperature in ° C
Cranbrook
JunJ
Relationship Between Total Monthly Water Use (L/P/D) & Mean Maximum Monthly Temperature in Kaslo 2009-2015
Total Monthly Water Use L/P/D
Mean Maximum Monthly Air Temperature in ° C
2009-2013
2014
Kaslo

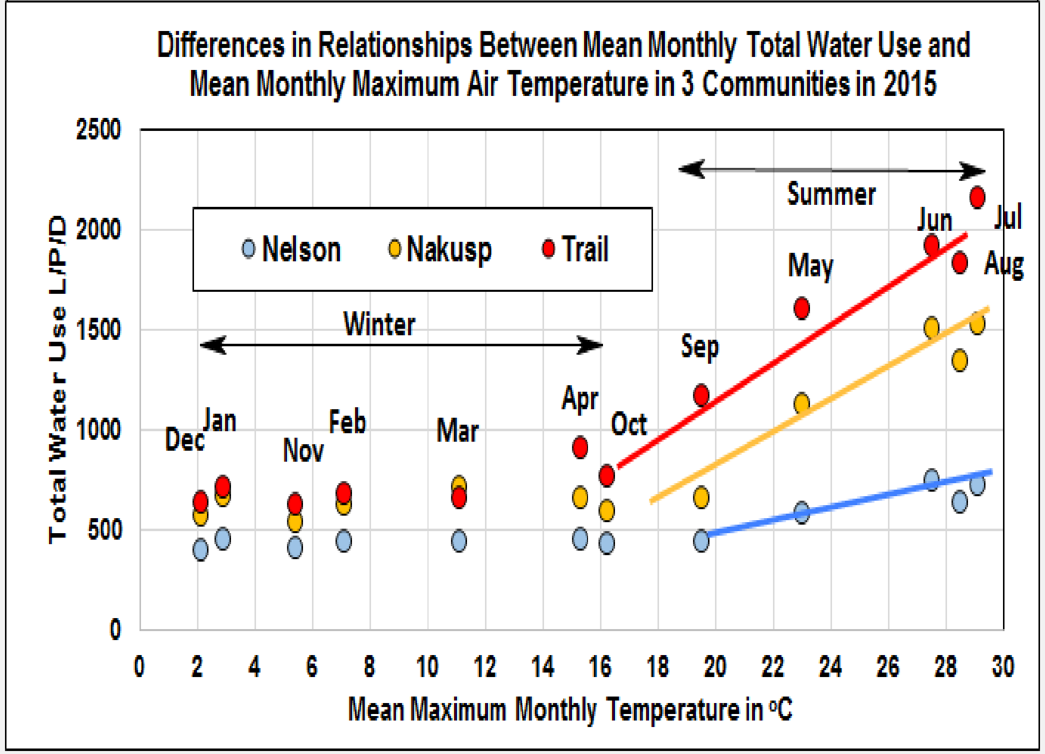

Relationship Between Total Monthly Water Use |(L/P/D) & Mean Maximum Monthly Temperature in RDCK-Erickson 2011-2015
2011-2014
2015
Total Monthly Water Use L/P/D
Mean Maximum Monthly Air Temperature in ° C
De
Jan
No
Feb
Mar
Apr
Oct
Sep
May
Aug
Jul
Jun
RDCK Erickson

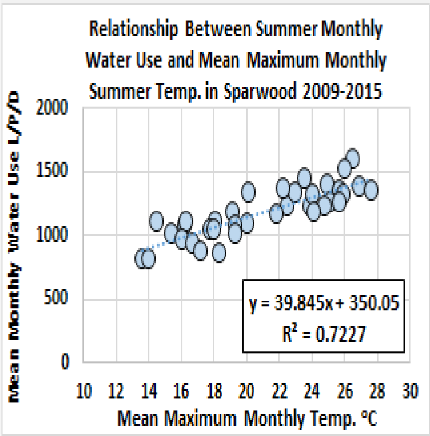

Relationship Between Total Monthly Water Use (L/P/D) & Mean Maximum Monthly Temperature in Elkford 2009-2015
2009-2014
2015
Total Monthly Water Use L/P/D
Mean Maximum Monthly Air Temperature in o C
Jan
Dec
Nov
Feb
Mar
Apr
Oct
May
Sep
Jun
Jul
Aug
Elkford

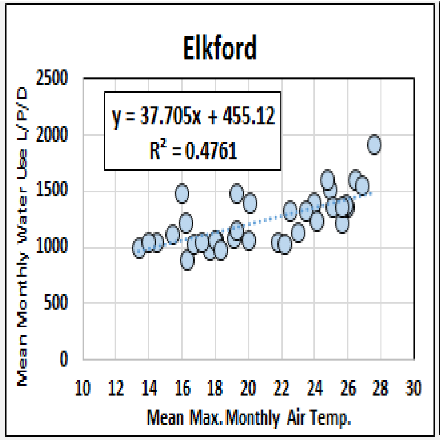

Relationship Between Monthly Water Use (L/P/D) & Mean Maximum Monthly Temperatures in Creston 2009-2015
2009-2014
2015
Total Monthly Water Use in L/P/D
Mean Monthly Maximum Air Temperature in ° C
DecJan
Nov
Feb
Mar
Apr
Oct
Sep
May
Aug
Jul
Jun
Creston

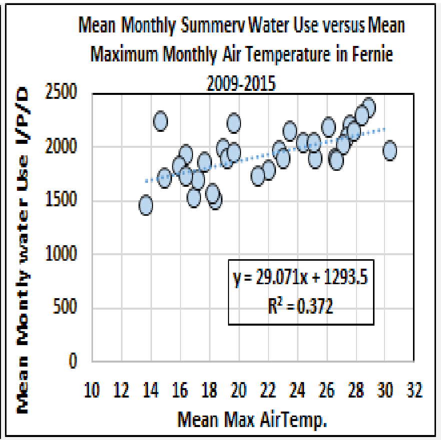

Relationship Between Total Monthly Water Use (L/P/D) & Mean Maximum Monthly Temperature in Fernie 2010-2015
2010-2014
2015
Total Monthly Water Use L/P/D
Mean Maximum Monthly Air Temperature in ° C
Jan
Dec
Nov
Feb
Mar
Apr
Oct
May
Sep
Jun
Jul
Aug
Fernie

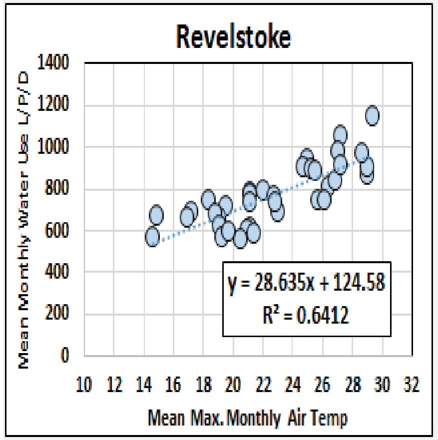

Differences in the Relationship Between Mean Maximum Monthly Air Temperatures & Total Monthly Water Use in 3 Different Communities in 2015.
Nakusp
Trail
Nelson
Winter
Summer
Dec
Jan
Nov
Feb
Mar
Apr
Oct
Sep
May
Jun
Aug
Jul
Total Monthly Water Use L/P/D
Mean Maximum Monthly Air Temperature in ° C

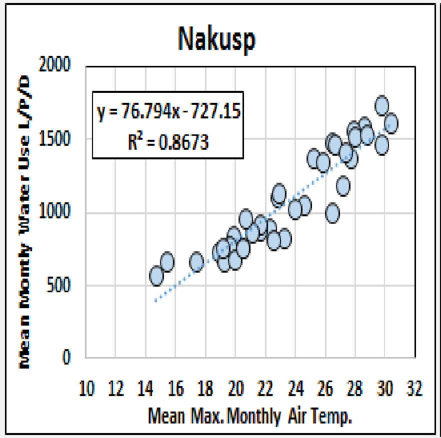

Differences in Relationships Between Mean Monthly Total Water Use and Mean Monthly Maximum Air Temperature in 3 Communities in 2015
Nelson
Nakusp
Trail
Winter
Summer
Dec
Jan
Nov
Feb
Mar
Apr
Oct
Sep
May
Jun
Jul
Aug
Total Water Use L/P/D
Mean Maximum Monthly Temperature in °C

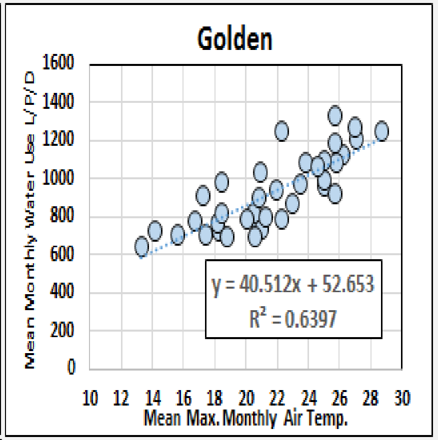

Relationship Between Summer Monthly Water Use and Mean Maximum Monthly Summer Temp. in Sparwood 2009-2015
y = 39.845x + 350.05
R² = 0.7227
Mean Monthly Water Use L/P/D
Mean Maximum Monthly Temp. °C

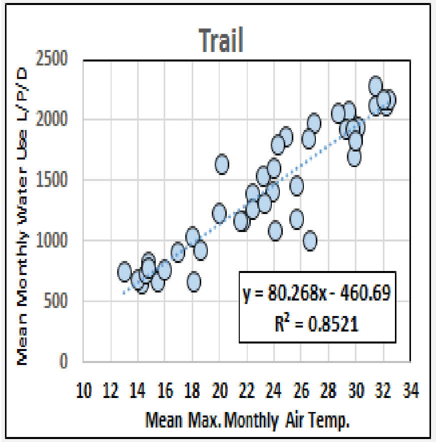

Elkford
y = 37.705x + 455.12
R² = 0.4761
Mean Monthly Water Use L/P/D
Mean Max. Monthly Air Temp.

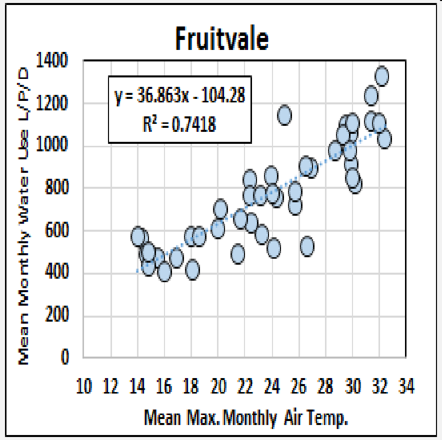

Mean Monthly Summerv Water Use versus Mean Maximum Monthly Air Temperature in Fernie 2009-2015
y = 29.071x + 1293.5
R² = 0.372
Mean Monthly water Use l/P/D
Mean Max AirTemp.

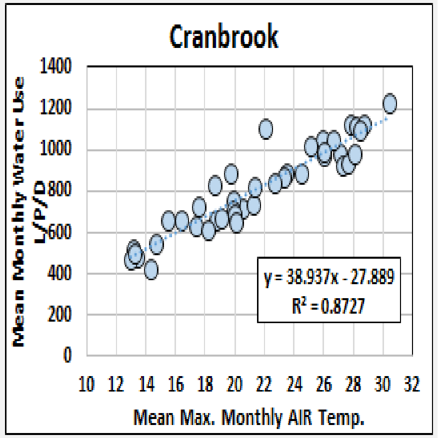

Revelstoke
y = 28.635x + 124.58
R² = 0.6412
Mean Monthly Water Use L/P/D
Mean Max. Monthly Air Temp

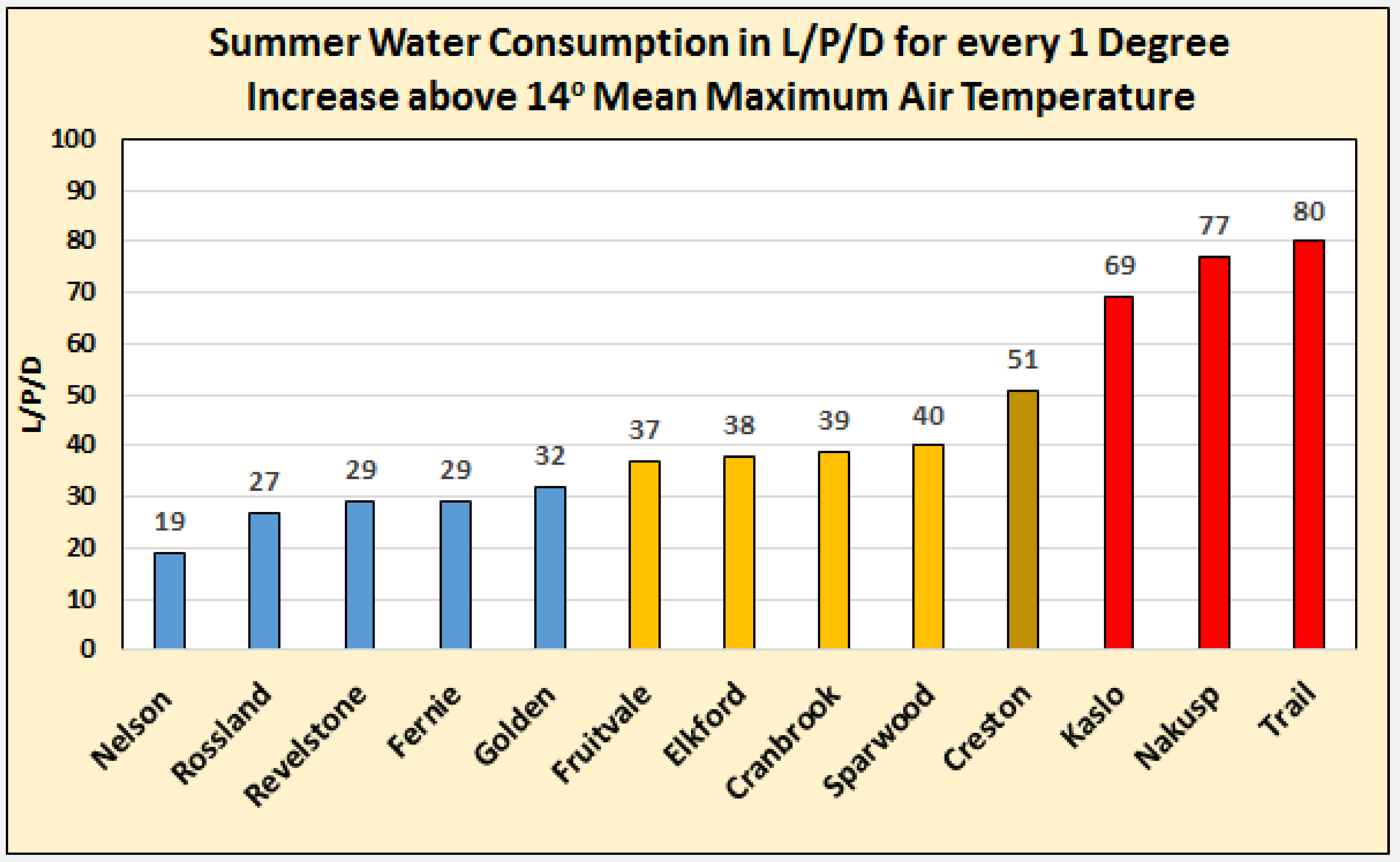

Nakusp
y = 76.794x - 727.15
R² = 0.8673
Mean Montly Water Use L/P/D
Mean Max. Monthly Air Temp.


Golden
y = 40.512x + 52.653
R² = 0.6397
Mean Monthly Water Use L/P/D
Mean Max. Monthly Air Temp.


Trail
y = 80.268x - 460.69
R² = 0.8521
Mean Monthly Water Use L/P/D
Mean Max. Monthly Air Temp.


Fruitvale
y = 36.863x - 104.28
R² = 0.7418
Mean Monthly Water Use L/P/D
Mean Max. Monthly Air Temp.


Cranbrook
y = 38.937x - 27.889
R² = 0.8727
Mean Monthly Water Use L/P/D
Mean Max. Monthly AIR Temp.


Summer Water Consumption in L/P/D for every 1 Degree Increase above 14° Mean Maximum Air Temperature
L/P/D
100
90
80
70
60
50
40
30
20
10
0
19
27
29
29
32
37
38
39
40
51
69
77
80
Nelson
Rossland
Revelstone
Fernie
Golden
Fruitvale
Elkford
Cranbrook
Sparwood
Creston
Kaslo
Nakusp
Trail

% Reduction in Total Water Use in 2014 & 2015 Compared to 2009 (N & W)

	Cranbrook		Fernie		Elkford		Sparwood		Golden		Revelstoke		Nakusp	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
Jan	-22	-25	-18	-2	5	7	-6	-19	-3	-17	-23	-16	5	5
Feb	-23	-25	-16	-9	17	3	-4	-17	-2	-22	-17	-11	13	11
Mar	-23	-20	-14	-17	10	-21	-3	-18	-7	-18	-18	-14	14	18
Apr	-16	-12	-14	-9	26	-31	-9	-24	-20	-20	-13	-10	23	16
May	-27	6	-22	-14	27	-12	-10	-9	-32	-14	-21	3	-10	35
June	-25	-10	-9	-5	10	-8	-24	-8	-30	-20	-27	-3	-25	11
July	25	12	25	17	31	-6	-4	-3	-4	-9	-20	-15	-16	-11
Aug	7	1	5	-10	23	4	0	5	-9	-19	-21	-16	-25	-15
Sep	-27	-25	4	-16	-27	-21	-30	-26	-3	-16	-24	-15	7	-26
Oct	-22	2	6	-29	-20	0	-16	-14	-5	-7	-22	-10	14	0
Nov	-11	12	11	-20	4	3	-20	-15	-20	-10	-16	-3	3	0
Dec	-8	13	19	-5	14	4	-25	-12	-16	-14	-15	-8	7	-2
Total	-13	-5	-3	-10	11	-7	-12	-12	-14	-16	-20	-10	-5	1

Yellow = Increases

Blue = Reductions

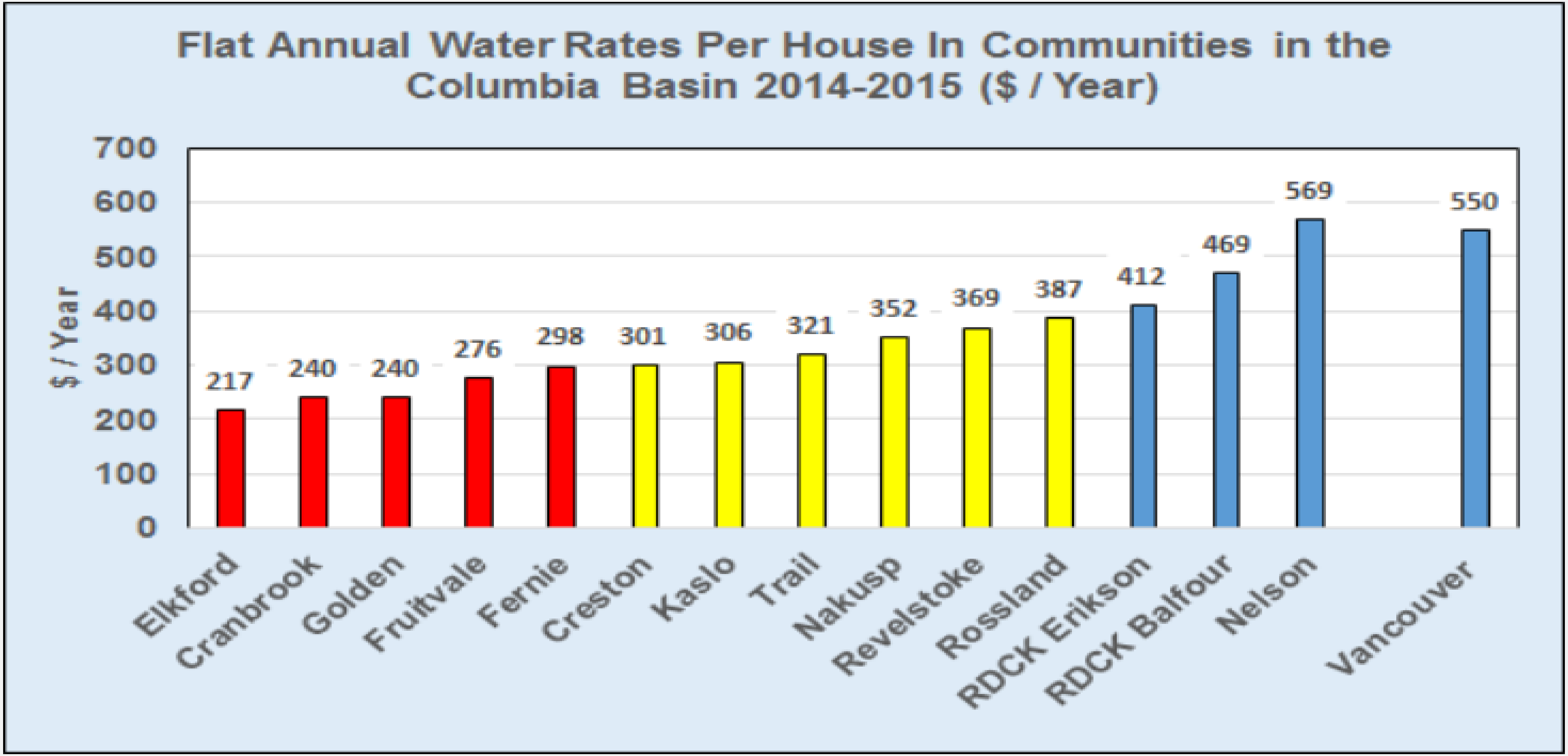
% Reduction in Total Water Use in 2014 & 2015 Compared to 2009 (S)

	Nelson		Kaslo		Rossland		Trail		Fruitvale		Creston		RD-Erickson	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
Jan	-10	-12	-29	-47	-21	-24	4	1	-19	-16	5	22	-19	1
Feb	-4	-10	-14	-40	-25	-31	20	7	-18	-22	25	14	1	-2
Mar	-4	-11	-31	-53	-23	-26	38	20	-22	-13	28	20	8	4
Apr	-5	-10	-44	-50	-24	-17	28	39	-24	-15	19	40	9	31
May	-9	7	-41	-2.2	-29	-10	-8	35	-28	9	0	55	1	95
June	-16	11	-45	-19	-31	-11	-18	3	-33	-14	-20	-13	15	81
July	17	10	-18	-21	-16	-16	10	9	-2	5	42	-10	27	1
Aug	11	-4	-30	-51	-9	-23	-8	-12	-25	-21	1	0	-27	-32
Sep	9	-6	-45	-55	-14	-48	-28	-35	-23	-35	-3	-11	-39	-46
Oct	-6	-14	-47	-41	-18	-27	-13	-14	1	-16	16	42	0	17
Nov	-10	-18	-51	-49	-26	-25	-9	-20	-15	-23	38	33	3	4
Dec	-8	-20	-46	-51	-31	-25	-23	-23	-16	-21	10	18	1	9
Total	-2	-5	-36	-39	-22	-23	-5	-2	-20	-14	12	13	-5	4

Yellow = Increases

Blue = Reductions

Flat Annual Water Rates 2014-15 For Single Residential Houses in Communities in the Columbia Basin ($ /Year)



Water Conservation Options

Basic Options:

Universal Metering (Smart Meters)

Volumetric Charge Rates (Bloc Rates)

Toilet Replacement Program (Low Flush)

Water Saving Devices

Recycling & Reuse (Grey Water)

Replace old Pipes & Fix Leakages

Lower Water Pressure

Summer Outdoor Use Options:

Rainwater Harvesting

Improve Soils to Hold More Water

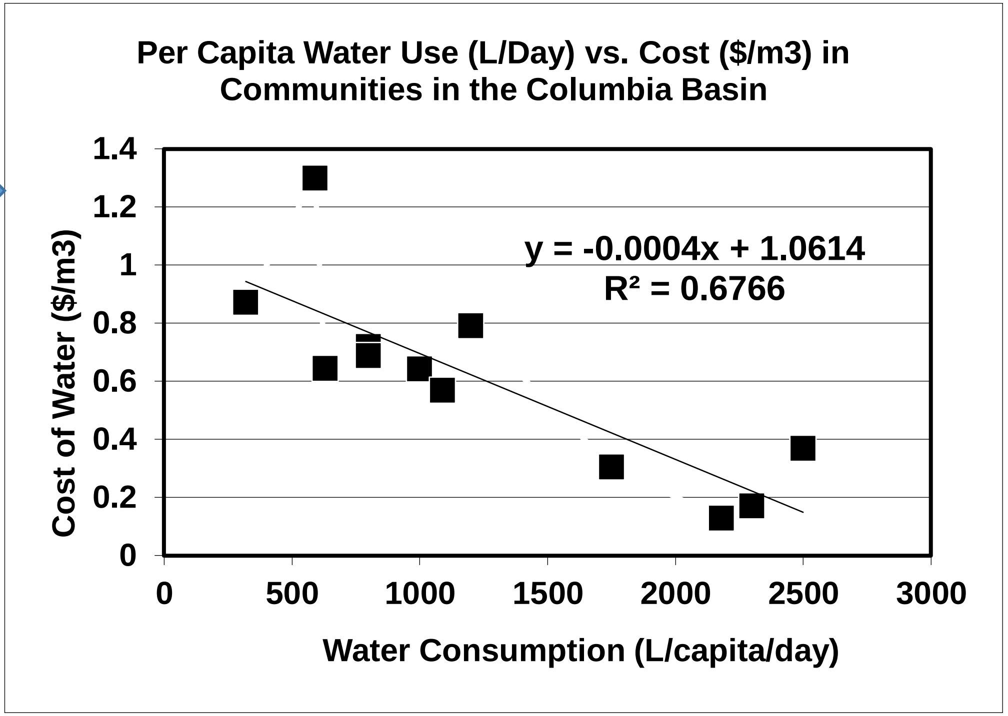
Efficient Irrigation

Xeriscaping

Yellow Lawns in Summer

Summer Restrictions (2 Days/Week)

Water Pricing and Block-Rates



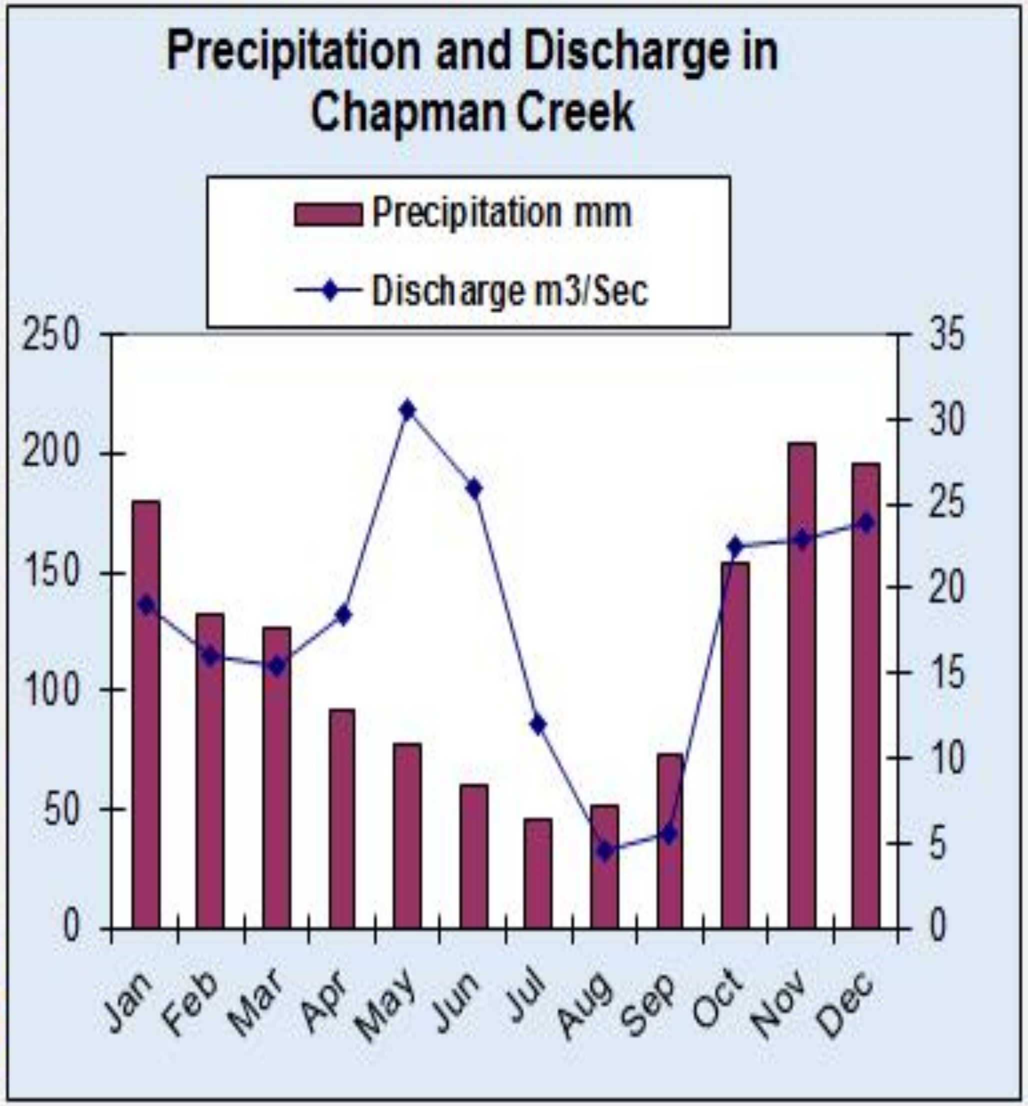
What Was Accomplished ?

1. Proper Water Accounting is a Complex Task
2. Requires System Monitoring and Calibration of System Metering
3. Universal Metering is Critical but Initial Cost Concerns (Can save 18-58% of Water)
4. Water Loss Manangement = Greatest Problem (old Infrastructure)
   (Detection issues Nov. or Feb between 1am & 4 am at Night)
5. Need for Asset Inventory and Replacement Planning
6. Equitable Water Pricing (Difficult without Metered Data)
7. Source Water Inventory, Planning & Protection
8. Education Program (Ambassador Program for Water Conservation)
9. Food Security and Irrigation

- Only 2 of the 15 Communities were unable to reduce their water Consumption in 2014 & 2015 (as opposed to the 2009 Baseline)
- All others Communities achieved a 3-39% reduction
- Leakages is the Greatest Problem (30-70%)
- The hot & dry 2015 Summer created new Challenges for Several Communities
- Some Successfully Addressed the Demand by initiating Summer Water Restriction

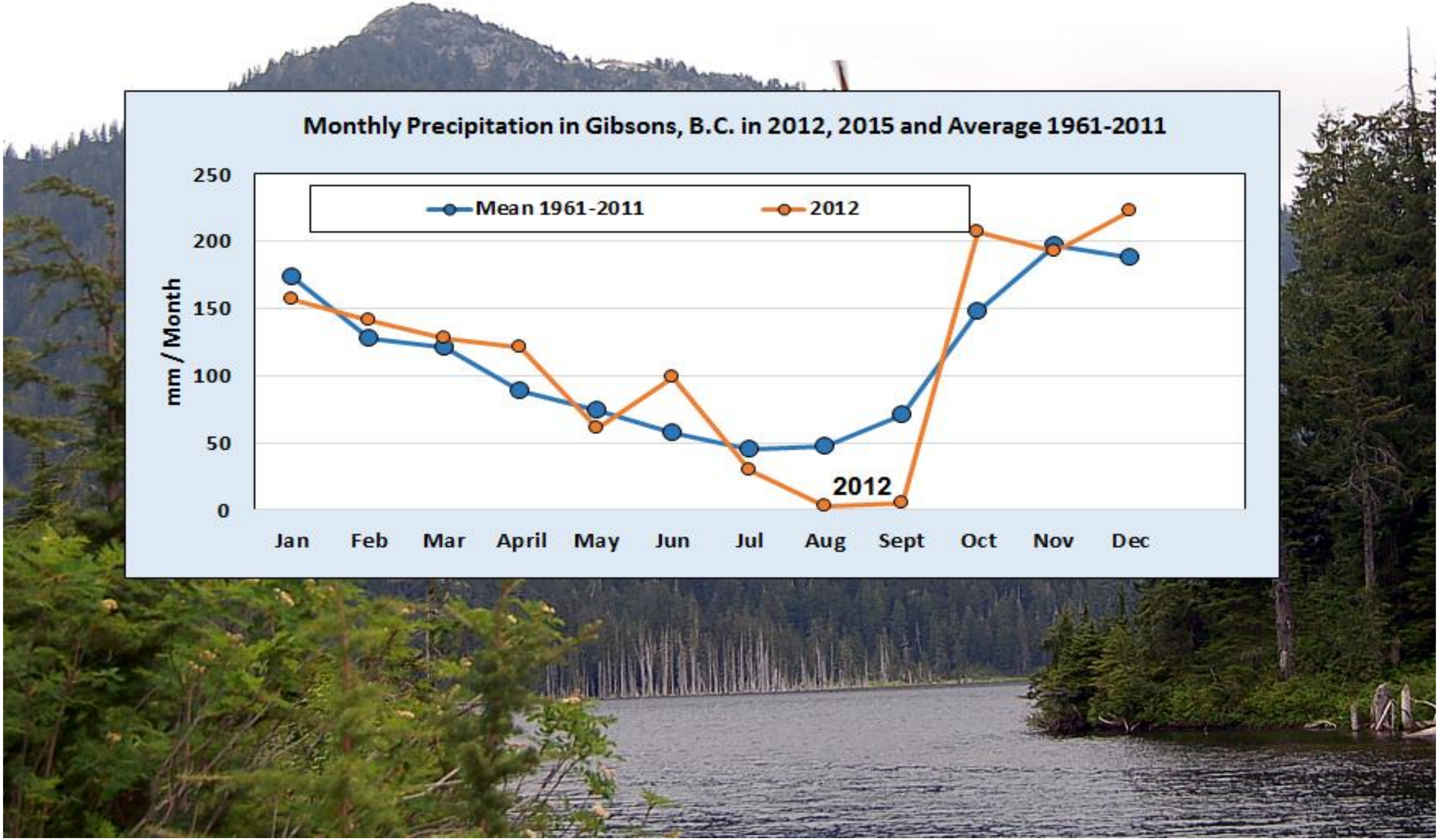

Coastal Mountains (Elevation 1400 m)
Chapman Creek Reservoir: Water Supply for the Sunshine Coast (25000 People)


Tetrahedron Provincial Park
Reservoir
Tuwanek
McNab Creek
Furry Creek
Porteau
Port Mellon
Gambier Island
Anvil Island
Sechelt
Selma Park
Population
Davis Bay
Roberts Creek
Hopkins Landing
Gibsons
Lions Bay
Bowen Island
Wigwam Inn
Iron Bay
Mt Seymour Provincial Park
West Vancouver
Belcarra
WESTWOOD PLATEAU
Vancouver
Coquitlam
EAST SIDE
Burnaby
New

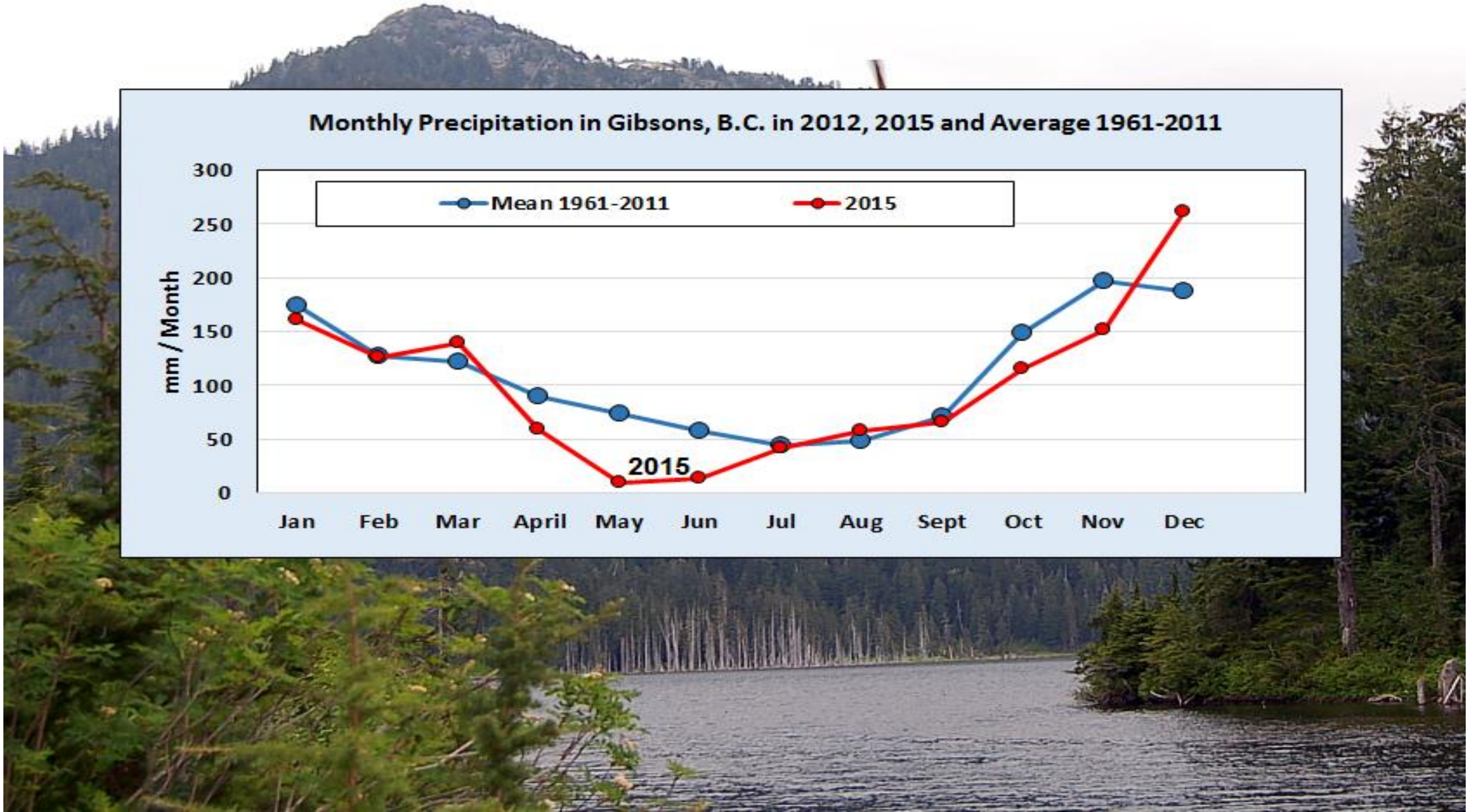

Precipitation and Discharge in Chapman Creek
Precipitation mm
Discharge m3/Sec
250
200
150
100
50
0
35
30
25
20
15
10
5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

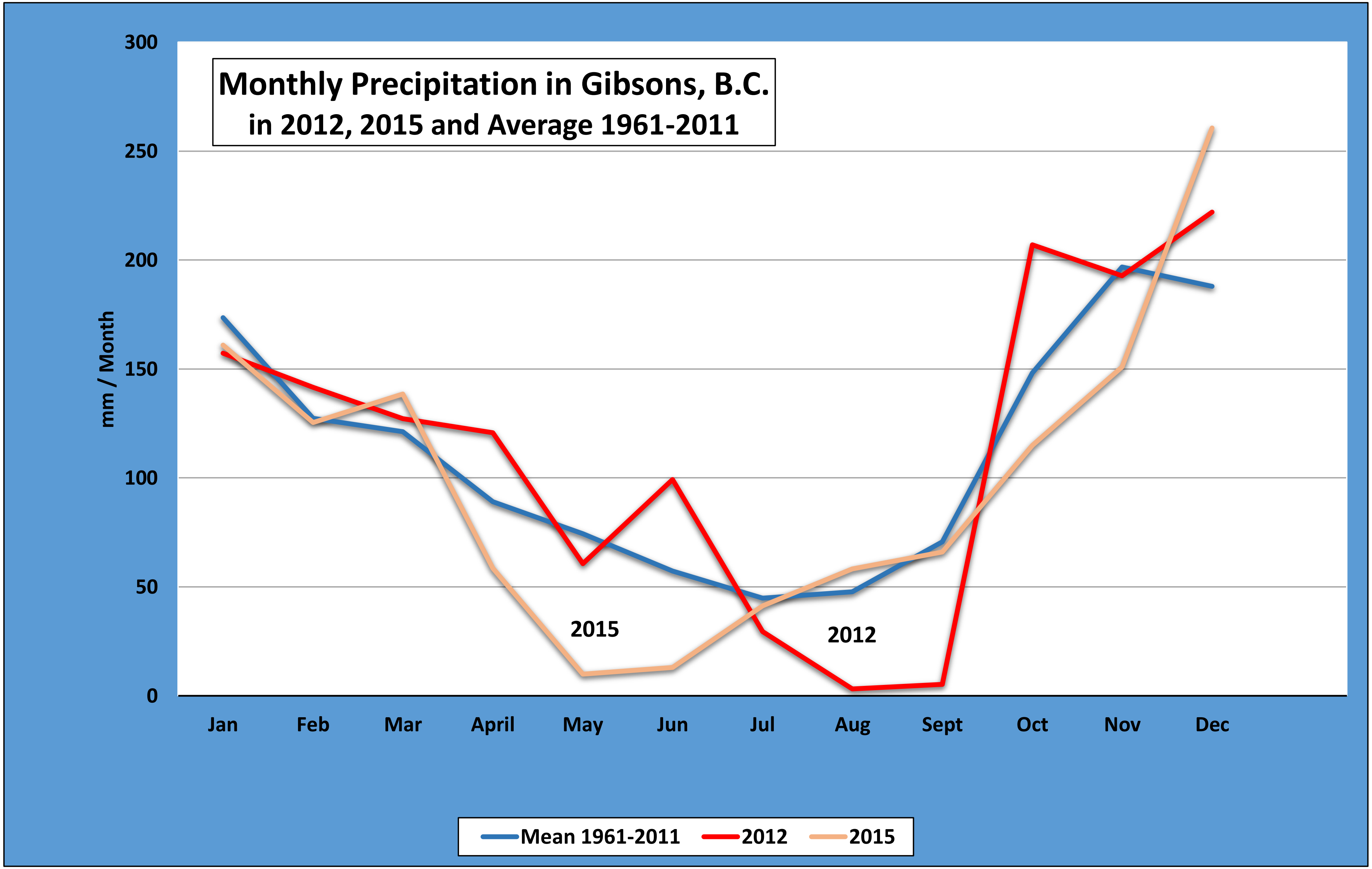
Chapman Creek Reservoir, Sunshine Coast, B.C.

Photo Sources:
Monte Staats 2014

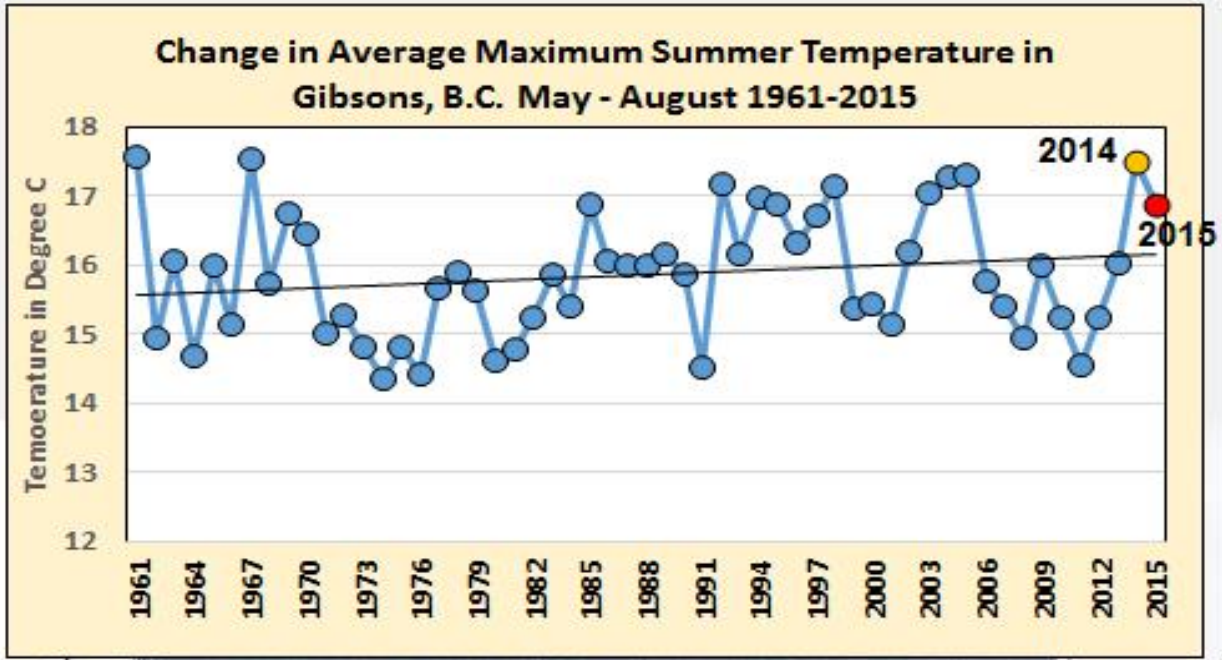


Monthly Precipitation in Gibsons, B.C. in 2012, 2015 and Average 1961-2011
Mean 1961-2011
2012
mm / Month
250
200
150
100
50
0
2012
Jan
Feb
Mar
April
May
Jun
Jul
Aug
Sept
Oct
Nov
Dec

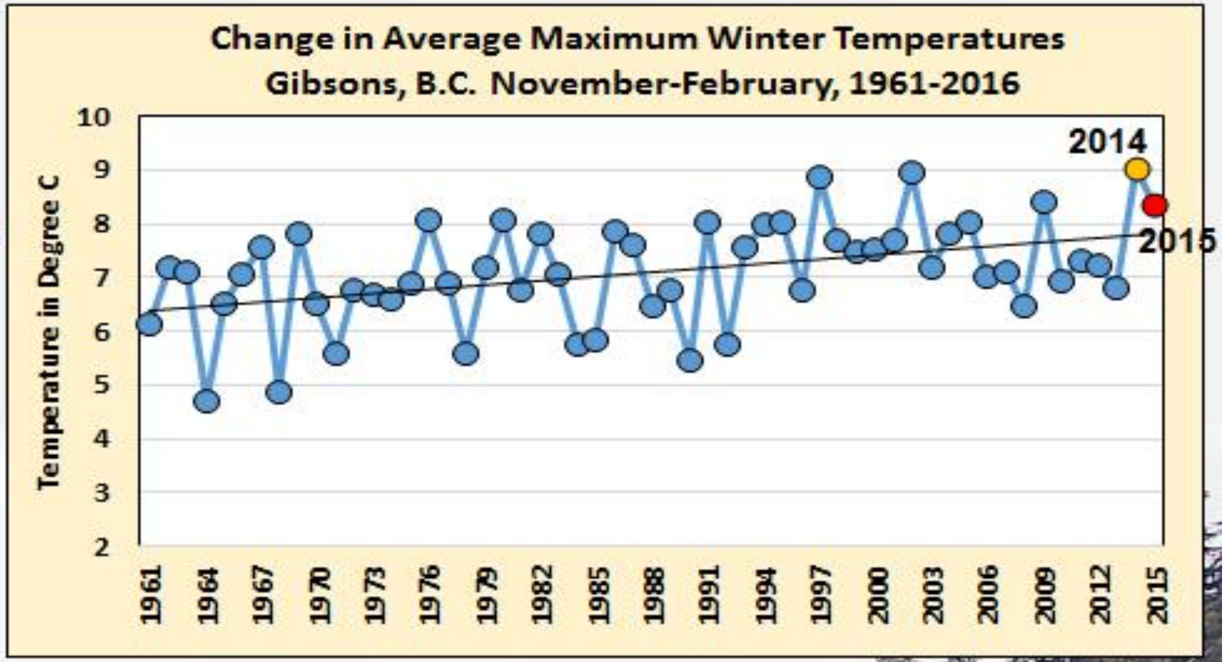

Monthly Precipitation in Gibsons, B.C. in 2012, 2015 and Average 1961-2011
Mean 1961-2011
2015
mm / Month
300
250
200
150
100
50
0
2015
Jan
Feb
Mar
April
May
Jun
Jul
Aug
Sept
Oct
Nov
Dec


Monthly Precipitation in Gibsons, B.C.
in 2012, 2015 and Average 1961-2011
mm / Month
300
250
200
150
100
50
0
2015
2012
Jan
Feb
Mar
April
May
Jun
Jul
Aug
Sept
Oct
Nov
Dec
Mean 1961-2011
2012
2015

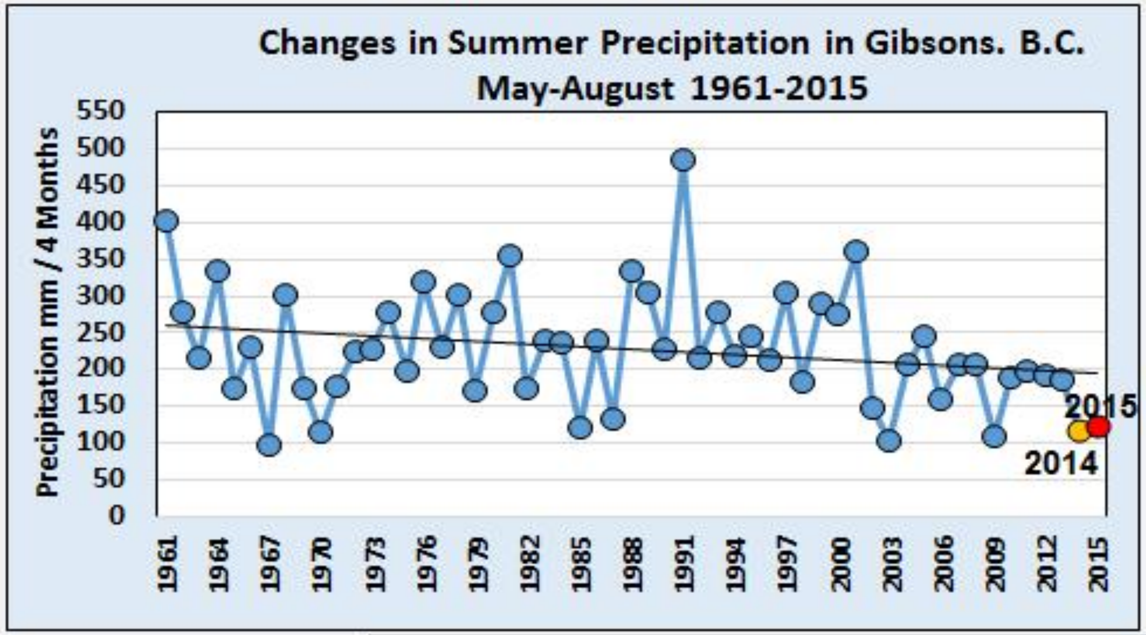
Average Summer Maximum Temperature



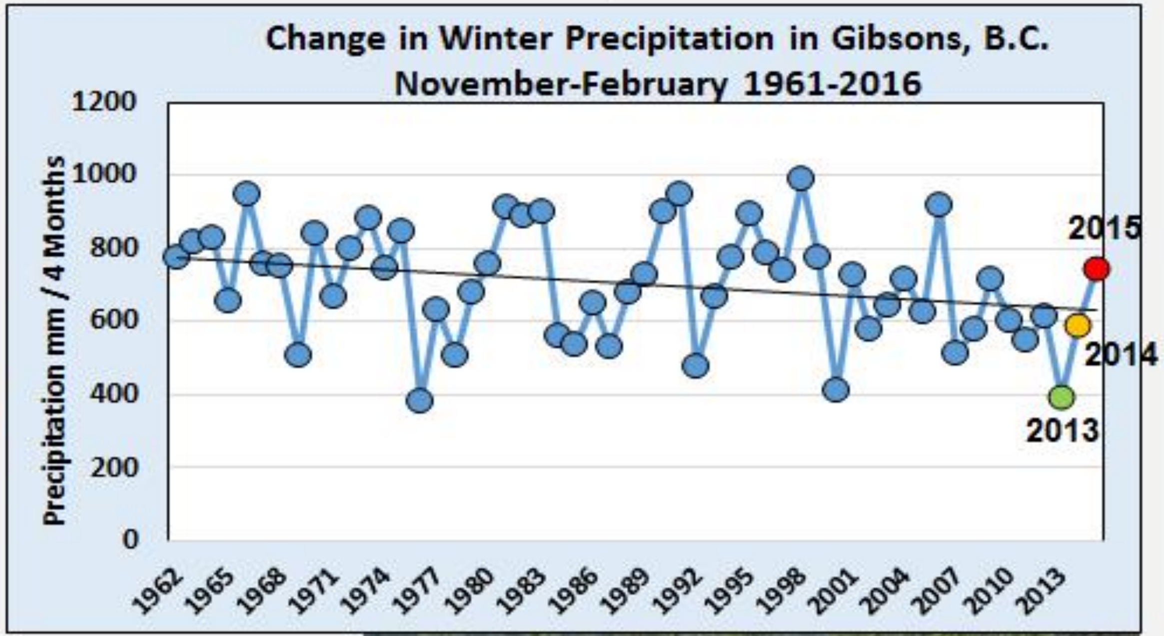
Average Winter Maximum Temperature



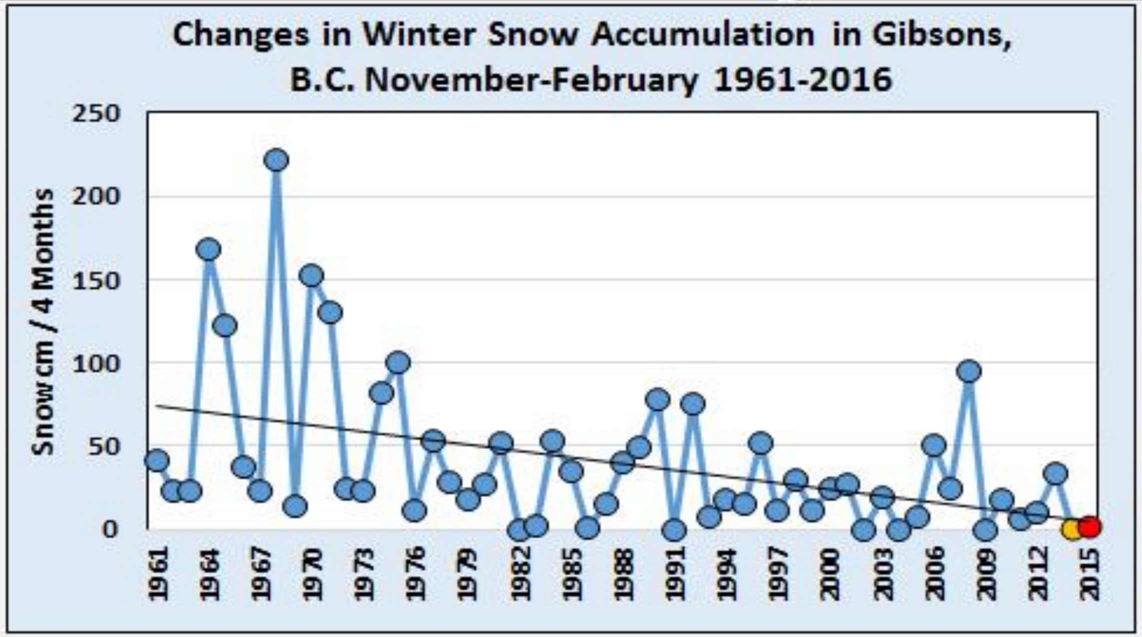
Summary Precipitation



Winter Precipitation



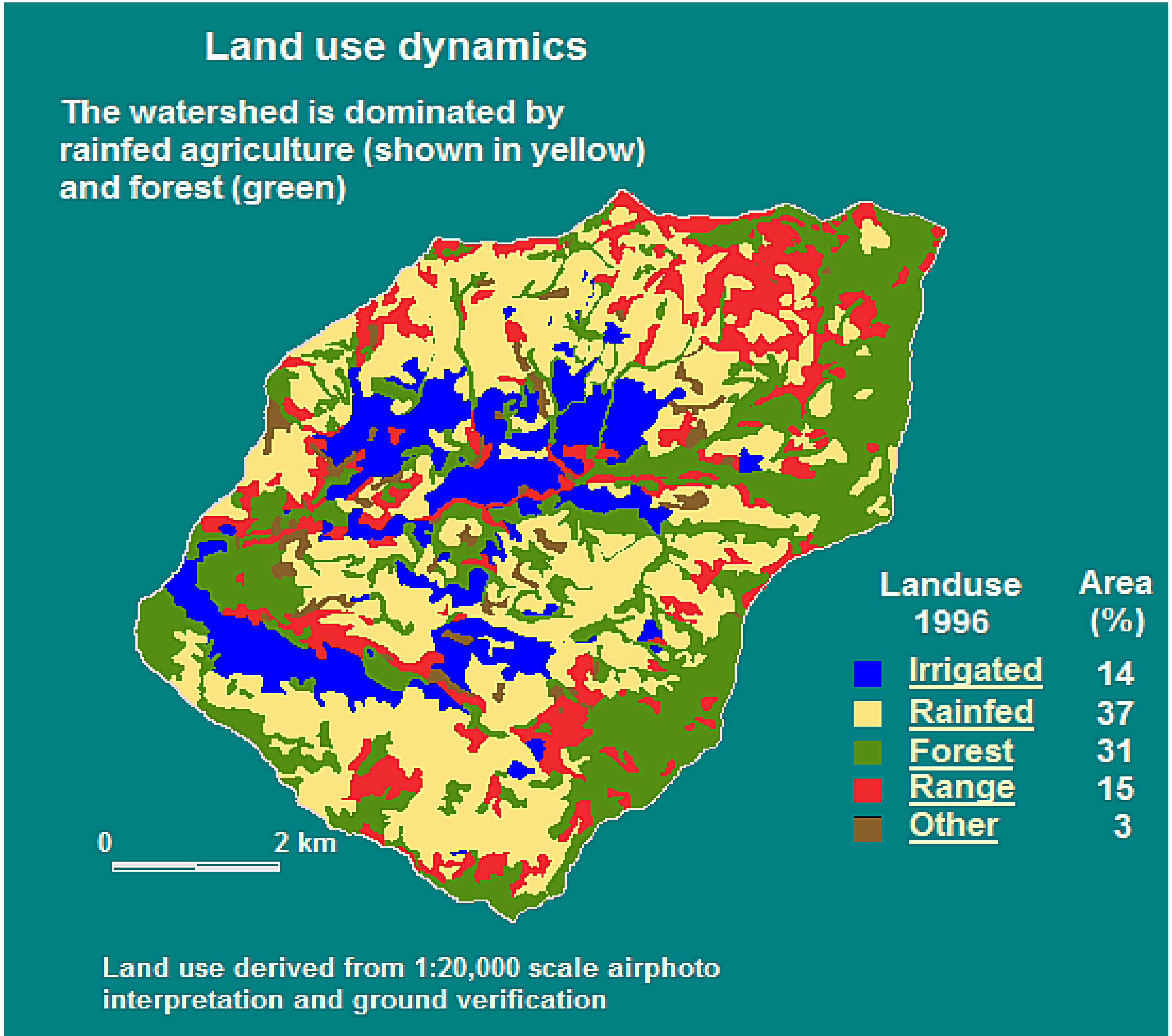
Winter Snow Accumulation



Water Management Challenges in Nepal

Hans Schreier, Land & Food Systems, University of British Columbia. Canada

Yarsha & Jikhu Khola Watershed Studies in Nepal

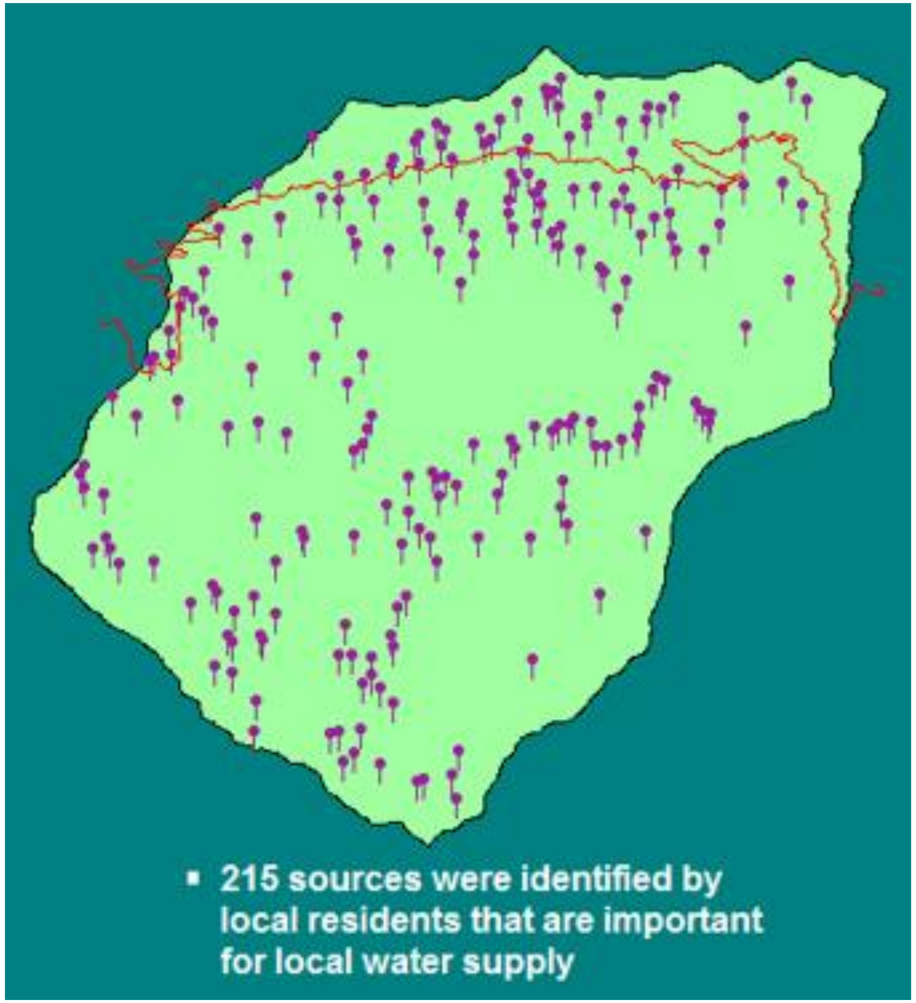


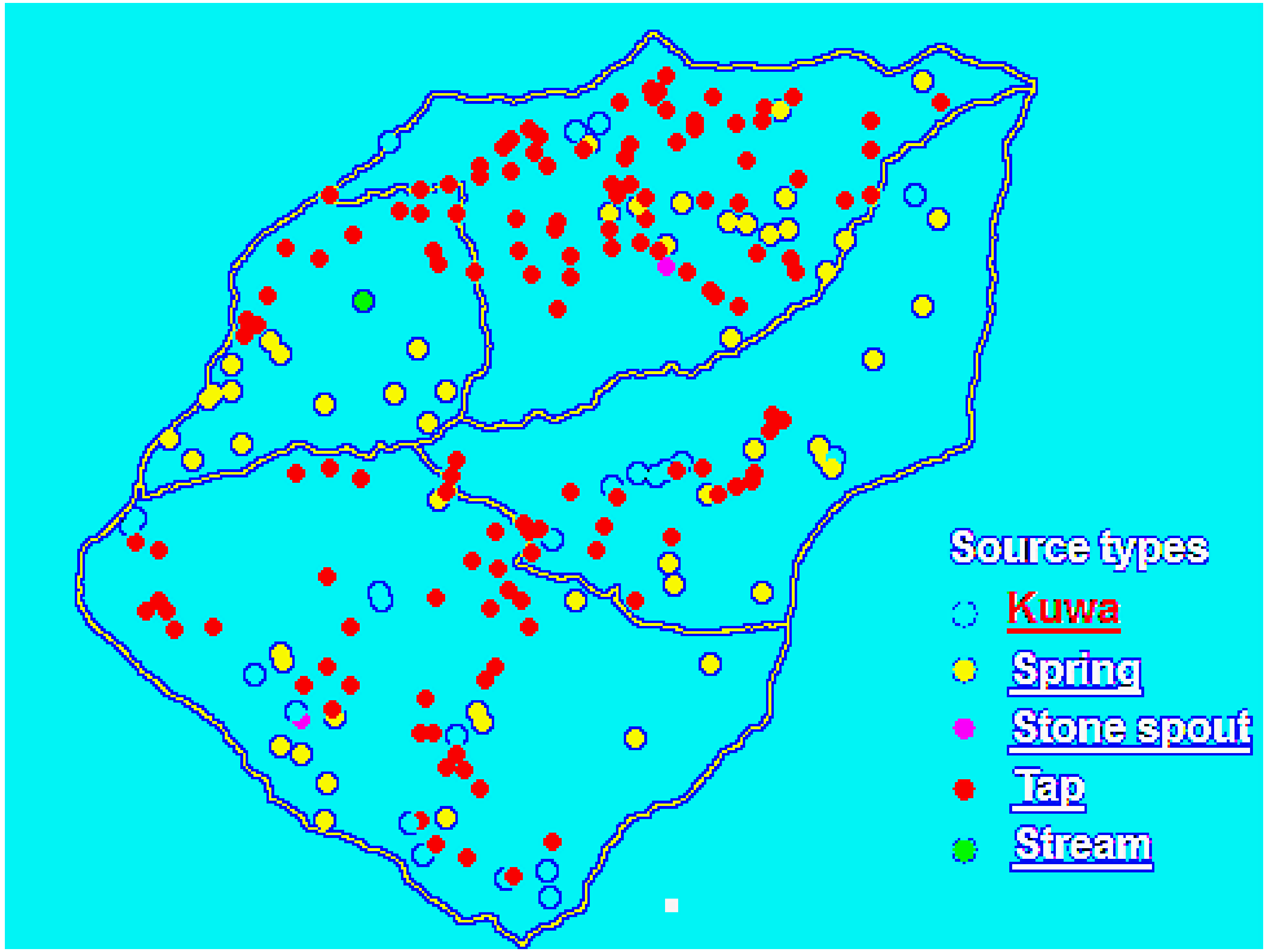
Monsoonal Climate Produces Contrasting Water Regime

Female / Male Questionnaires

Questionnaire	Female	Male	Both
General information			X
Household and animal water supply	X		
Agricultural water supply		X	
Perception of water & water issues			X

- The separate questionnaires reflect gender based roles and responsibilities in water management.
- Female and male enumerators interviewed the female and male household heads respectively.


▪ 215 sources were identified by local residents that are important for local water supply

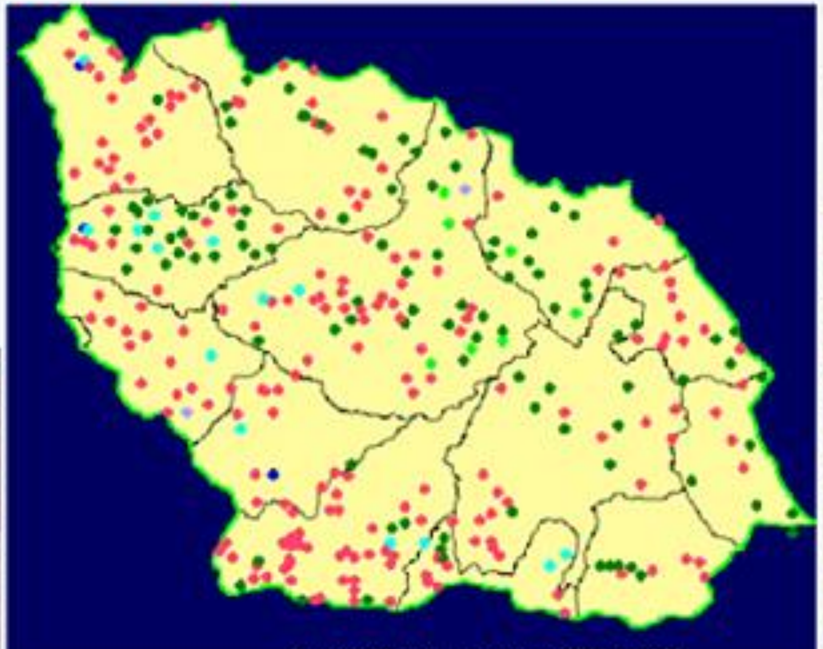

Source types
Kuwa
Spring
Stone spout
Tap
Stream

Public Water

Type of Public Water Sources

Source types

- Kuwa
- River
- Spring
- Stone spout
- Tap
- Well



Source: Water use survey 1999, n=356

Different Water Sources Used for Domestic Purposes

Spring :locally called mul

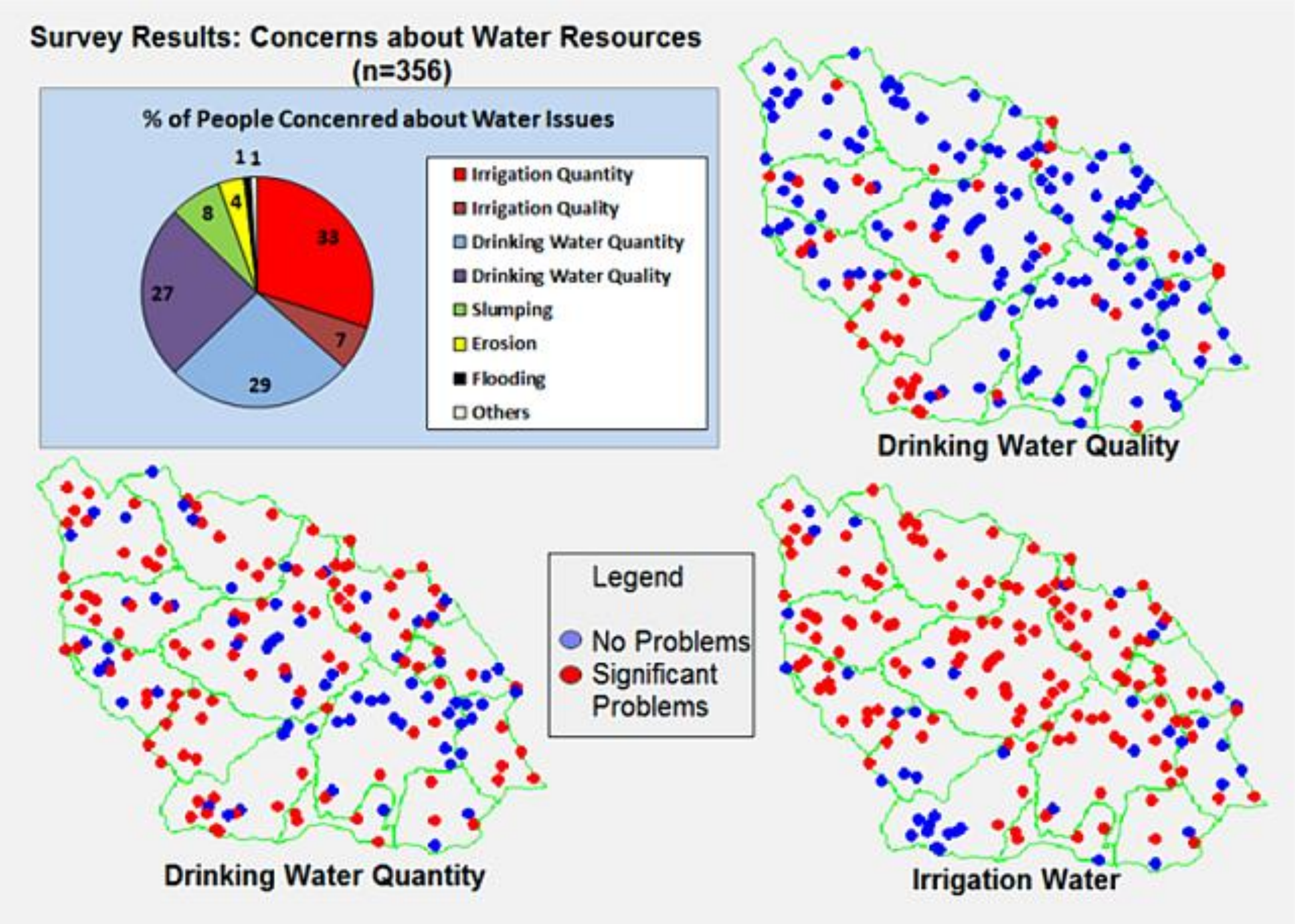
River Source: locally called khola

Kuwa: Reservoir tank storage water coming from springs

Stone Spout: locally called Dhunge dhara diverting water from river or spring, stone spout carved

Well: locally called inar, shallow groundwater source (< 5 m)

Tap: locally called dharo, water diverted from springs or rivers

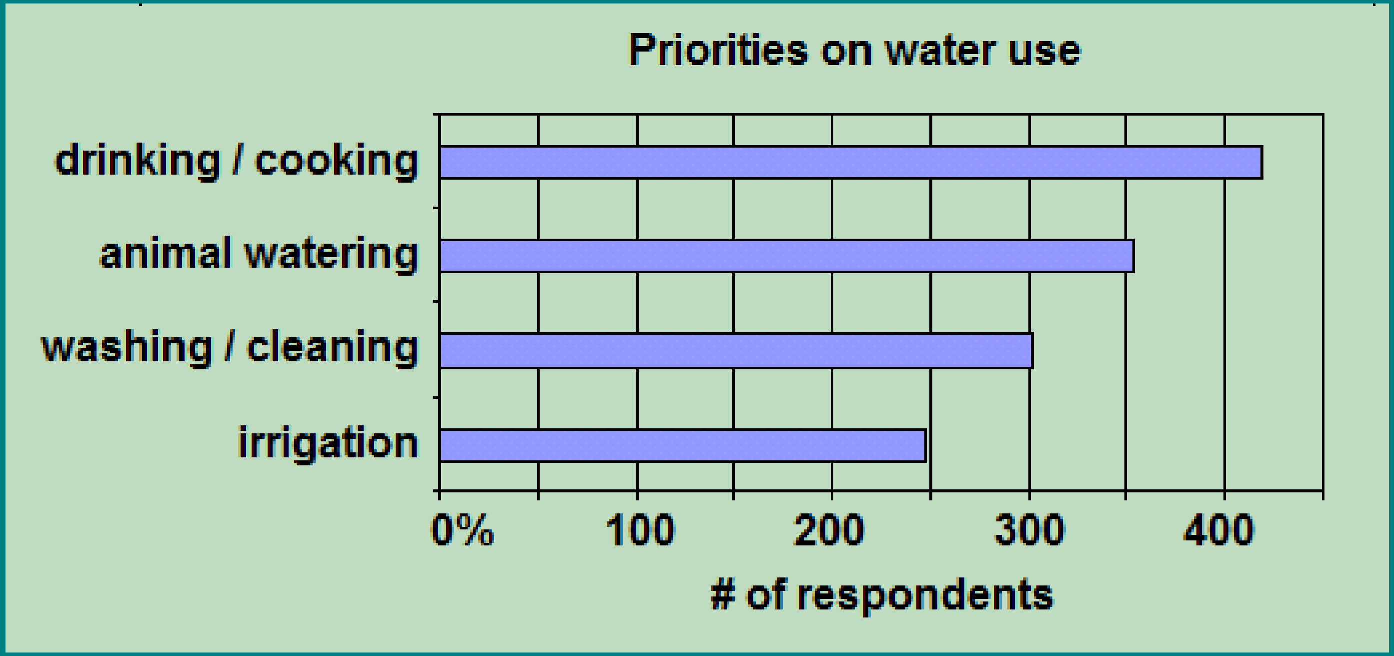


Survey Results: Concerns about Water Resources (n=356)
% of People Concenred about Water Issues
33
7
29
27
8
4
1 1
Irrigation Quantity
Irrigation Quality
Drinking Water Quantity
Drinking Water Quality
Slumping
Erosion
Flooding
Others
Drinking Water Quality
Legend
No Problems
Significant Problems
Drinking Water Quantity
Irrigation Water

Issues

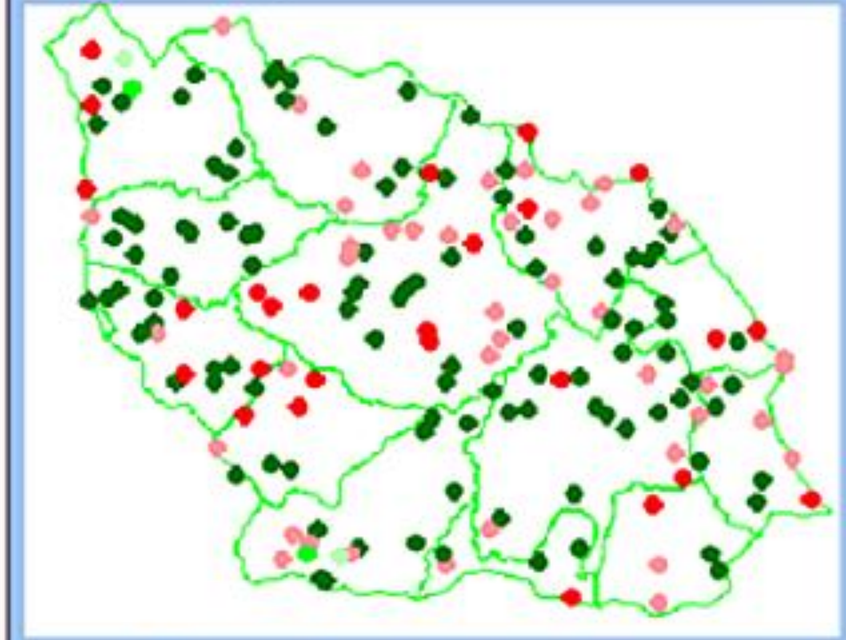
Priorities

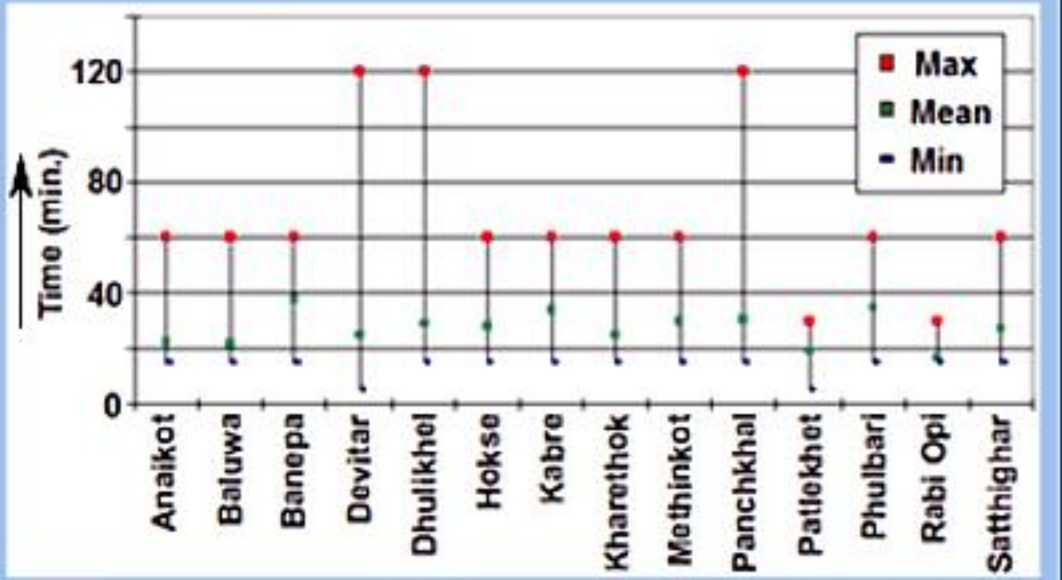
Perceptions



- The highest priority is given to the use of water for drinking and cooking, followed by animal husbandry.

Daily Water Collection Time in Different Villages in the Watershed



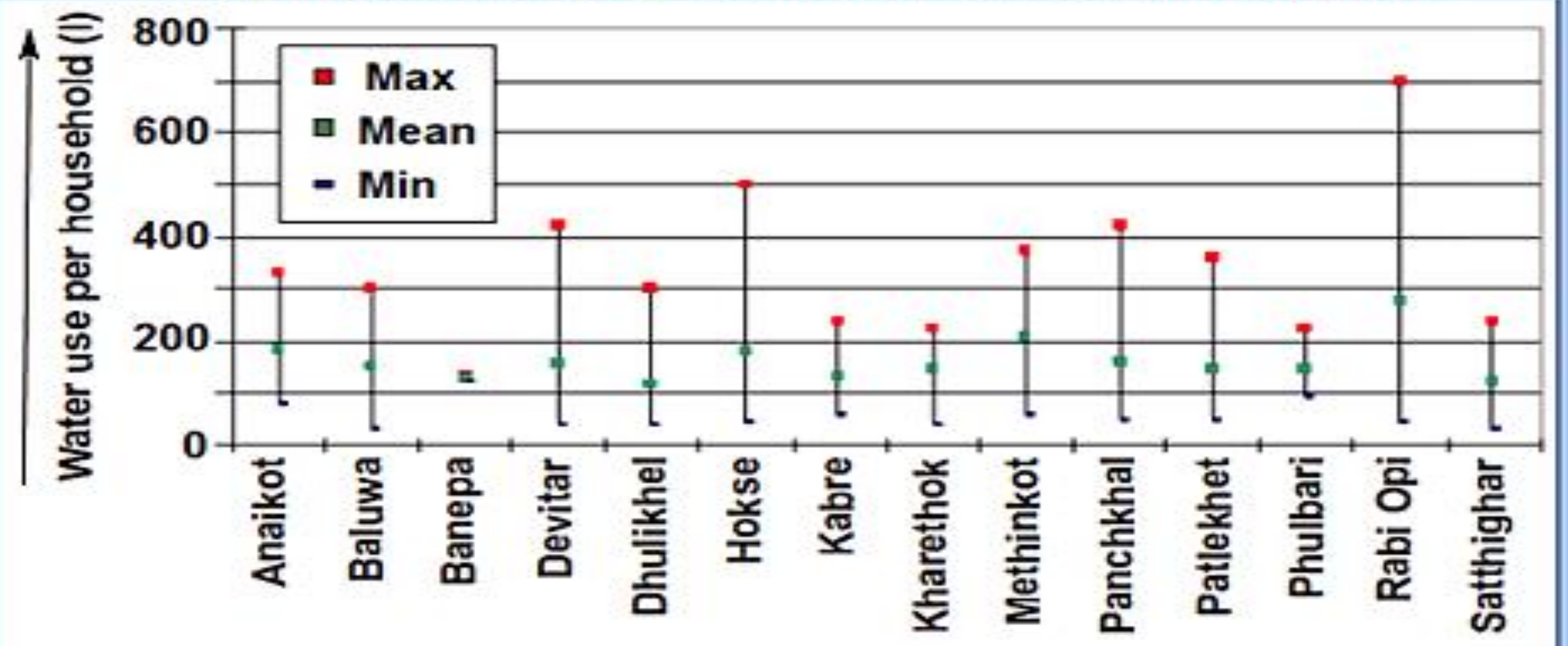


Time to fetch Water (Minutes)

- < 5
- 5 - 10
- 10 - 20
- 20 - 30
- 30 - 120

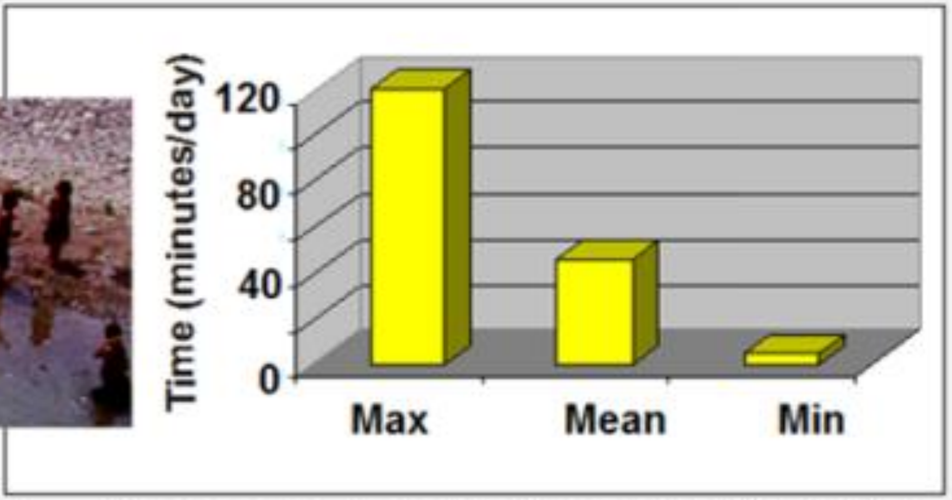
Overall Average Collection Time = 26 Minutes
Typical Collection Time: 15 Minutes to 1 Hour
Maximum Recorded = 2 Hours (Panchkhal, Devitar)

Daily Amount of Water Collection per Household in L/Day



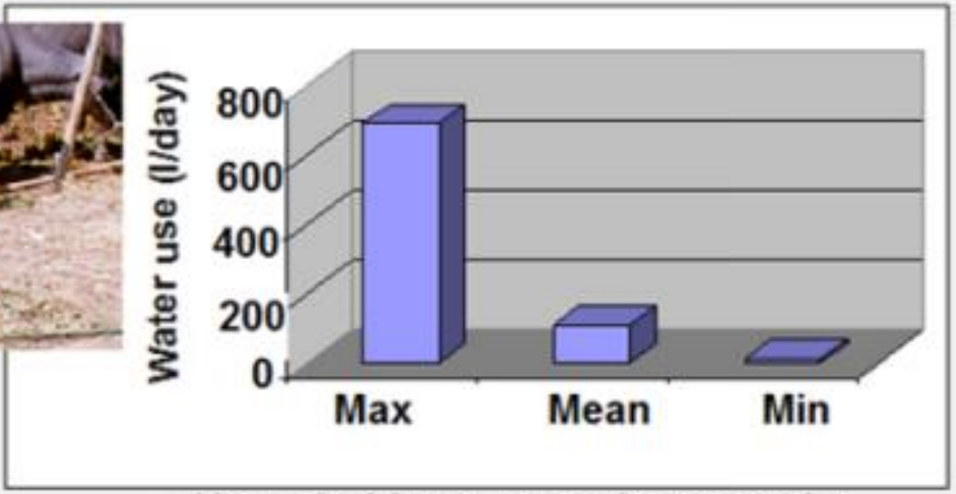
Average per capita water consumption 23 l /day

Guidelines for rural water supply design = 45 l /day



Time Spent to Water Livestock & Amount of Water Used for Livestock

On average, households spend 45 minutes per day watering animals
Maximum time spent = 2 hours / day
Livestock are either water onsite or taken to water 'holes'

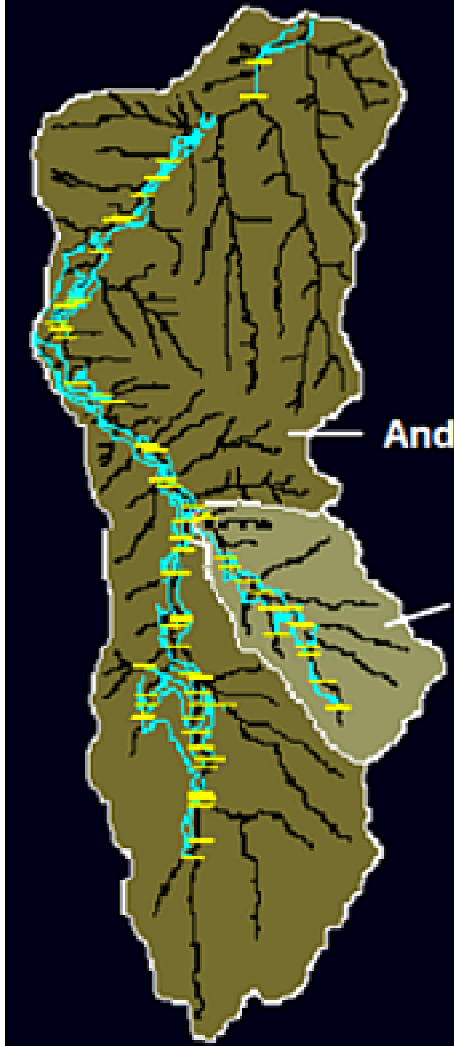


Household water requirements for livestock averaged 106 litres per day

Number of Check-Dams

Irrigation Water Management: Check dams

The effectiveness of the irrigation system in diverting floodwater is evaluated by comparing flow from the Andheri and Kukhuri basins



Basin characteristics	Kukhuri basin	Andheri basin	Ratio
Contributing area (ha)	72	532	7.4
Irrigated area (ha)	7	37	-
# Dams	14	62	-

Water Harvesting for Irrigation

Two demonstration cisterns were constructed

Surface runoff is collected from the catchment area and stored in an underground tank
30,000 L tank ideal to grow vegetables
High capital costs ($1000 US for 30 cubic m)

Cost & Space are Key Factors that Determine the Amount of Water to Be Collected.

The Best Option is to Use the Collected Water for High Value Crops with the Most Efficient Irrigation System (Drip Irrigation)

Collected during Monsoon, Used During Dry Season when Crop Values are High

Low cost drip irrigated cauliflower, Nepal

Drinking Water Collection Systems

"Thai" jar - rainfall rooftop collection method

Directs monsoon rainfall from the roof of a dwelling into a gutter system leading to a holding tank. 13 trial systems constructed in Jhikhu Khola. Cost $ 80 US per unit

Water use - summary

Irrigation and drinking water supply are the key water issues

Irrigation supply perceived to have decreased in the last 5 years

Drinking water access has improved through the use of polythene pipe

Sediment is perceived to be a major problem in drinking water supply

Summary: Managing Water at the Municipal Level

WATER CONSERVATION

1. WATER METERS
2. VOLUME BASED PRICING
3. LOW FLUSH TOILETS
4. LEBELING WATER USE ON APPLIANCES
5. OUTDOOR WATER USE REDUCTION
6. RAINWATER HARVESTING
7. 30 CM OF TOPSOIL BEFORE PLANTING GRASS
8. XERISCAPING (REDUCING SIZE OF LAWN)

SOURCE WATER PROTECTION

SURFACE WATER

1. SOURCE CONTROL
2. LAND USE CONTROL (ZONING)
3. BUFFER ZONES
4. WETLANDS
5. BENEFICIAL MANAGEMENT PRACTICES

GROUNDWATER

1. CONFINED vs. UNCONFINED
2. VULNERABILITY ASSESSMENT
3. LAND USE CONTROL OVER CAPTURE ZONE
5. SOURCE CONTROL

Source Water Protection

Requires a Multi Barrier Approach

- Requires Source Protective Measures
- Comprehensive Water Treatment Options (active & passive)
- A Safe Supply Network
- A Monitoring Program in Place
- A Contingency Plan in Case of Failure

Examples of Contamination of Concern from Human Activities

Nutrients

Manure
Fertilizer
Human &
Livestock Waste
Air Pollution

Nitrate
Phosphate

Pathogens

Human Waste
Livesock Waste
Wildlife
Recreation

Giardia
Cryptosoridium
E. coli
Campylobacter

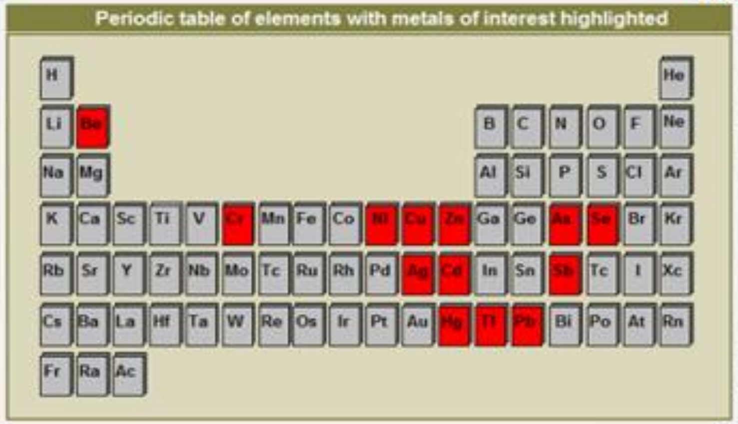
Sediments

Sediments from Land Use
Activities & Fires

Turbidity
Color
Fe, Mn

Metals

Road Transport Zn & Cu



Hydrocarbons & Organics

Hydrocarbon
Long Distance
Transport by Air

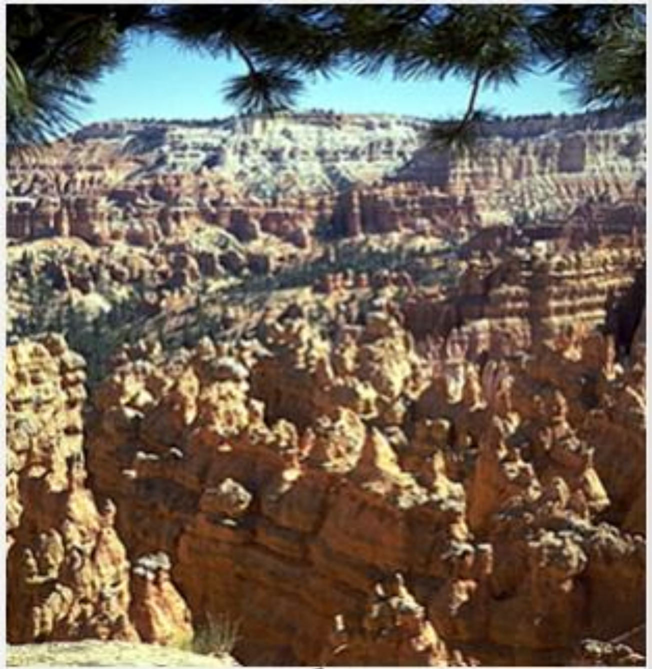
Chloninated Organics
Pesticides
Exotic Chemicals

Natural Processes Influencing Source Water

Influence of Bedrock on Water Quality

Igneous Rocks

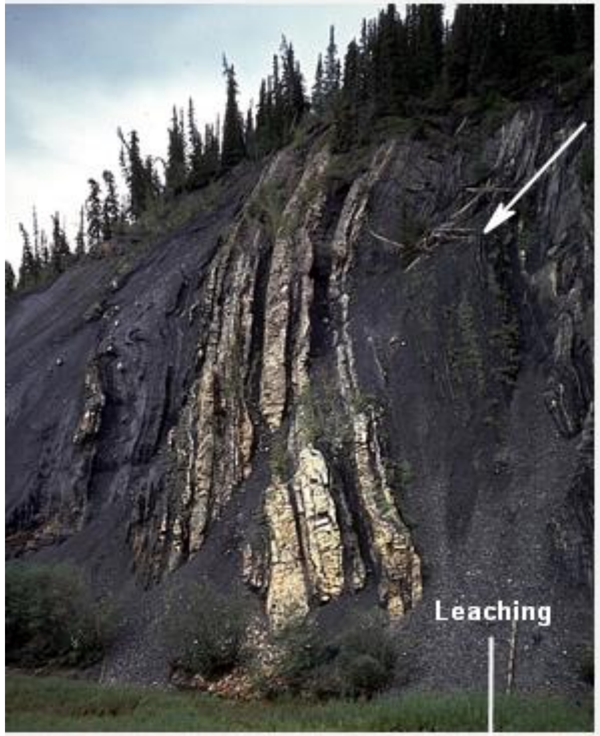
Granite (light Color) Volcanic (dark Color)	Soft Water, Slightly Acidic, Low Nutrient Content High in Nutrients and Cations, Variable pH



Limestone

Sedimentary Rocks

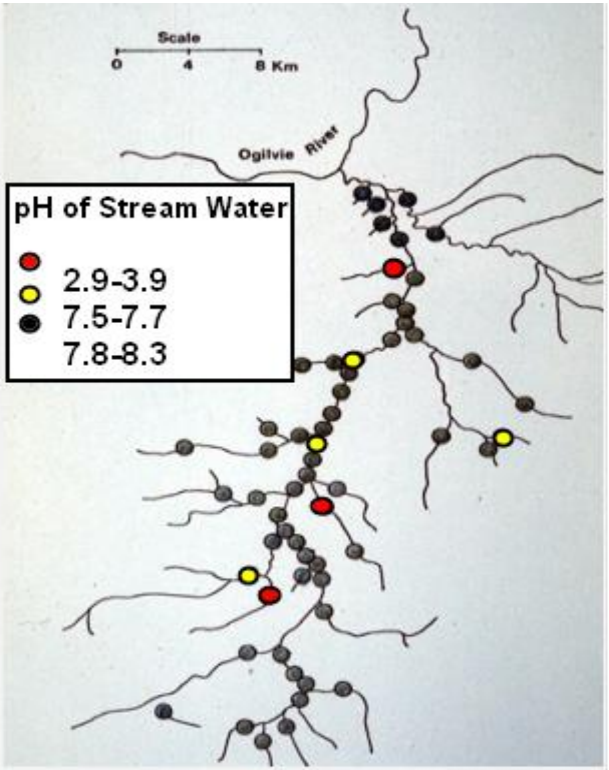
Sandstone Shale Limestone	Soft Water, Slightly Acidic, Low Nutrient Content Variable pH, High Nutrients, High Buffer and Exchange Capacity Hard Water, Alkaline, High Ca, Mg-Carbonate, High Buffer Capacity



Black Shale
Contains Pyrite (FeS)

Oxidizes into H_2SO_4
when exposed to Air

Spatial Distribution
of Streamwater pH



Limestone in
Adjacent Mountains

Chemical Interactions

Protecting Mountain Lakes

Characteristics of Mountain Lakes:

Lakes are primarily oligotrophic (Low nutrient content)
High Biodiversity in Aquatic Organisms
(Many different algal and invertebrate species)
Highly sensitive to nutrient input

What are the Issues about Mountain Lakes?

- Rapid Increases in Temperature
- Airborne Deposition in Dust & Rain
- Changes in Organic Matter Input
- Alterations due to Glacial Retreat

Rapid Increases In Temperatures in Mountain Lakes

Mountain Lake Temperatures	**Increases = 0.34 ^{o} C/ Decade**
Air Temperature	**Increases = 0.25 ^{o} C /Decade**
Ocean Temperatures	**Increases = 0.12 ^{o} C/Decade**

Source: Hampton et al. 2016. Rapid &highly variable warming of lake surfaces around the Globe. Mountain Views, CIRMOUNT, Vol 10(1): 5-8

Reasons of Temperature Increases:

Less Cloud, More Radiation
Less Ice Cover (Loss of Insulation)
Higher Temperatures = More Evaporation
(Shallow Lakes are more Susceptible

Impacts of Lake Warming

Warmer Water Holds Less O2
Decreases Algal Growth, Less Feed
Higher Chem. Concentrations
(due to More Evaporation)
Changes Food Web
Increases Primary Productivity
Changes in Species Composition

Airborne Dust & Nutrient Deposition

- Airborne Dust from desertification, mining operations, agricultural and construction activities is resulting in deposition of phosphorus, metals and organic chemicals into remote mountain lakes that changes the chemistry of these sensitive oligothrophic lakes
- Nitrogen in airpollution from fertilizers, manure application and transportation activities is enriching the lakes with an essential nutrient that changes the lake chmistry and the aquatic food web.

Impacts:

- **The combined input of nutrients (N & P) results in a shift form an oligotrophic state into a meso-trophic state, which increases to production of blue-green algae at the expense of diatoms.**
- **Oligotrophic lakes have little buffer capacity and the Nitrogen enriched precipitation is d acidifying lakes and shift the nutrient regime to promote Eutrophication.**

Challenges in Protecting Mountain Lakes

Mountain Lakes are excellent indicators of climate change and environmental Impacts
Sediment cores provide the history of changes (Fossil Records & Chemical Changes)

Problems:

- Most Mtn. Lakes are oligotrophic and are higly sensitive to changes in flow & inputs
- More than 50% of pristine mountain lakes have been stocked with fish & mysis.
- Long Distance Transport of Air Pollution is difficult to control
- Climate warming is affecting temperatures which interact with vegetaion changes
- Glacier fed lakes will lead to flow alterations & changes the sediment regime

Options:
Reduce Air Pollution Globally (Difficult)
Enhance Wetlands in Heawaters
Consider Liming Lakes (Limestone Pebbles)
Monitor Changes

Dilemma: Assist in speeding up the natural processes or let nature do the work over time

Time to say Good Bye – Arrivederci – Dhanybaed , Have a great course!

Thank you for all my wonderful Italian Friends for their support
And for allowing me to communicate with you

If Interested, here is a information source on Water in International Development:

http://wmc.landfood.ubc.ca/webapp/WID

Building a Wetland in Honduras

The last Beer in the Atacama Desert

Building a Suspension Bridge in Nepal


THANK YOU !