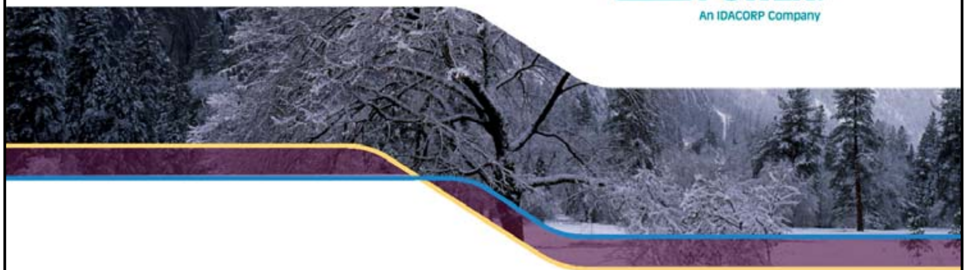


Idaho Power Company's Cloud Seeding Program

Shaun Parkinson, PhD, PE

Presentation Overview

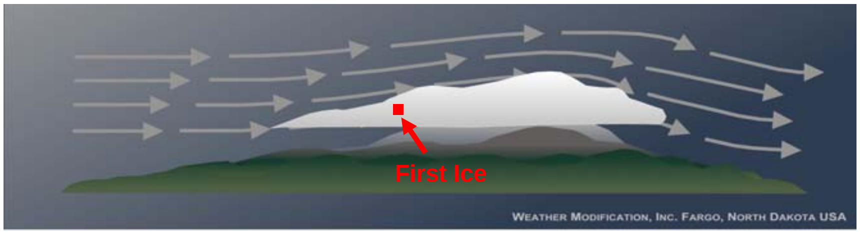
- What is cloud seeding?
- How we know cloud seeding works…
- Perceptions…
- IPC's cloud seeding program…
  - Payette
  - Upper Snake
- Benefits
  - Increased Runoff…
  - Increased Generation…

What is cloud seeding?

- The term cloud seeding has been used to describe:
  - Fog suppression (airports)
  - Hail suppression (reduce crop and property damage)
  - Rainfall enhancement (water supply augmentation)
  - Snowpack enhancement (snowpack augmentation)
- Our focus is **<u>snowpack</u>** enhancement
- In particular – IPC does winter orographic cloud seeding

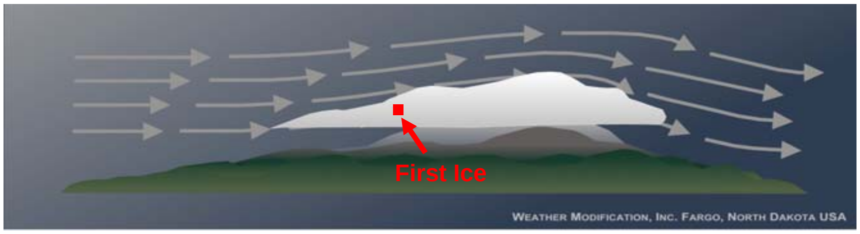
Winter Orographic Cloud Seeding

- As air is forced up and over mountains, it cools.
- If moist enough, it condenses to form a cloud of tiny water droplets.
- Cloud droplets do not freeze at 0°C (32°F). Instead, they supercool, remaining liquid at much colder temperatures.
- Eventually, ice gets introduced into these supercooled clouds, usually at temperatures colder than about -12°C (+10°F). Ice formation is induced by tiny particles called *ice nuclei*.



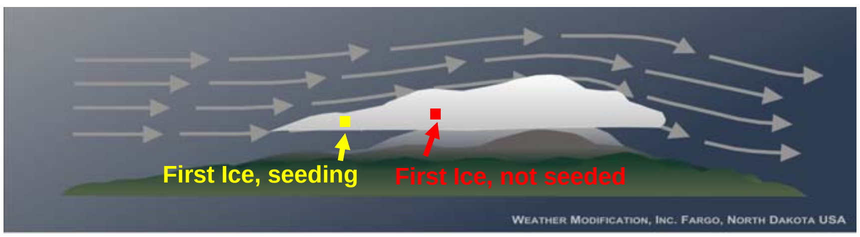
Winter Orographic Cloud Seeding

- Once ice forms, the particles grow quickly, forming flakes that become large enough to fall out as snow.
- Ice crystals continue to grow and may become large enough to fall as snow as they travel beyond the peak.
- As air continues over a mountain it may descend and warm. Crystals that haven't fallen as snow may be too small to fall, or they may melt and evaporate.



Winter Orographic Cloud Seeding

- *Cloud seeding* provides additional ice nuclei that function at warmer temperatures, allowing ice formation to begin sooner.
- This occurs at temperatures as warm as -5°C (+23°F), though more effectively at -8°C (+17°F) or colder. (The majority of natural ice nuclei become effective between -15°C to -20°C (+5 to -4°F).)



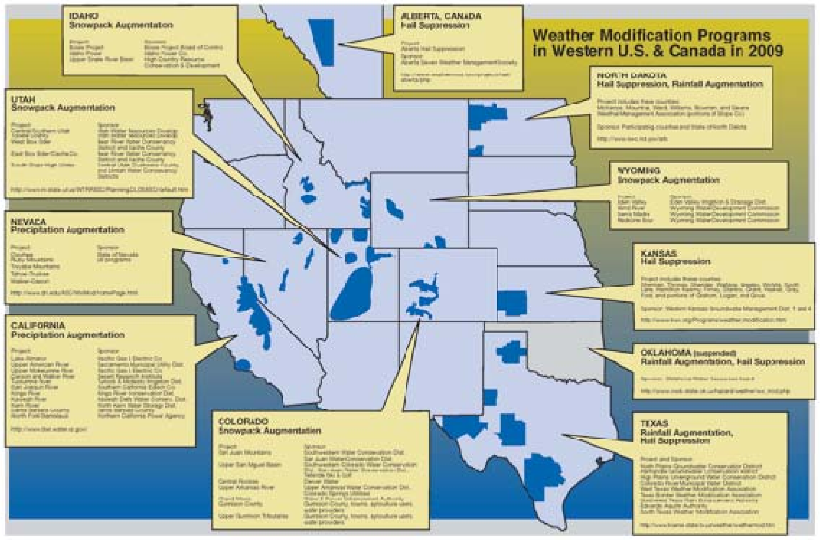
Winter Orographic Cloud Seeding

- *Snowfall is thus increased incrementally* because more ice crystals have a better opportunity to grow and fall as snow while over the mountain.
- *Cloud seeding* enhances the efficiency of converting supercooled cloud water into snow, increasing precipitation (snowfall) efficiency. Otherwise, this cloud water would likely pass over the mountain and evaporate.

Cloud Seeding Summary

- Cloud seeding provides mother nature with ice nuclei
- But, it is only effective when ice nuclei are limiting and nature is performing the other required precipitation processes
  - cloud seeding doesn't create clouds to seed – it will not cure a drought!
- Effectiveness depends on:
  - temperatures,
  - available water in the atmosphere,
  - ice nuclei properties,
  - cloud droplet and natural ice distributions
- Several agents can be used as ice nuclei, with silver iodide (AgI) being the most common used in commercial cloud seeding.

Cloud Seeding Programs - WMA



Silver Iodide Distribution

- In commercial programs, silver iodide is burned to release silver iodide particles (ice nuclei) of an appropriate size to the atmosphere.
- <u>Ground generators</u> - Acetone – silver iodide solution is burned in a propane flame.
- <u>Aircraft</u> - silver iodide is incorporated into a flare, or solution is burned.

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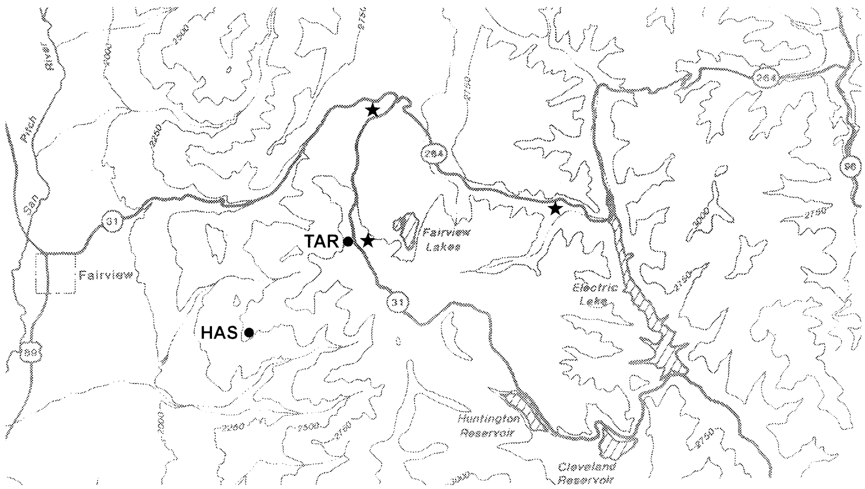
  - Water Temperature Benefits…

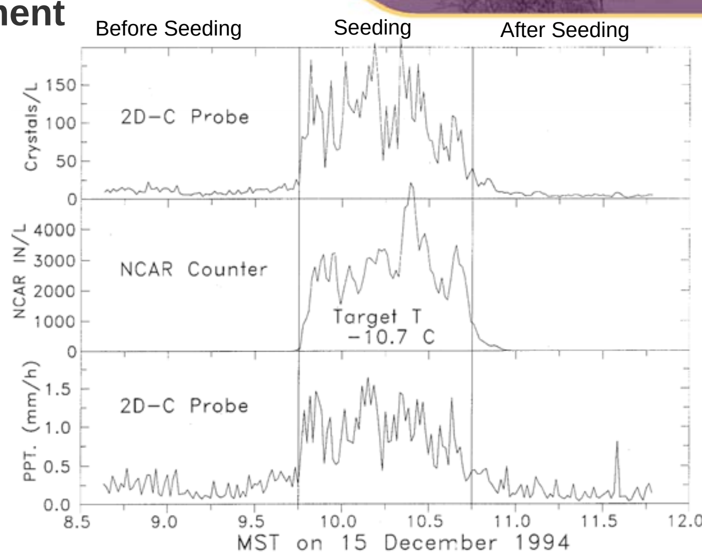
Cloud Seeding

- Lots of evidence that it works in laboratory and controlled conditions.
- The big question – how do we know it puts snow on the ground?
- Plume tracing – UT pulsed seeding experiment
- Trace chemistry (IPC’s dual tracer)
- Aircraft data collection

UT Pulsed Seeding Experiment



UT Pulsed Seeding Experiment



IPC's Dual Tracer Assessment

Approach

- IPC needed to demonstrate that project can effectively put snow in target area, and that seeding increases snowpack as expected.
- Independent contractors performed assessment
- Co-located seeding and tracer generators – ground and aircraft
  - Release seeding and tracer aerosols at same rate
- **Nucleating** particles (silver iodide) incorporated into snowpack through either ice nucleating (seeding) process **or** scavenging
- **Non-nucleating** particles (inert tracers) incorporated in snowpack through scavenging process **only**.

Co-located Generators

IPC's Dual Tracer Assessment

Approach (cont.)

- Following seeding, analyze snowpack for evaluation of trace levels of silver, indium, and cesium as well as snowpack density
- Ratio of silver to tracer (ex. Indium) in the snow pack gives an indication of how much silver deposited by ice nucleating vs. scavenging processes.

Sampling Snow Pack

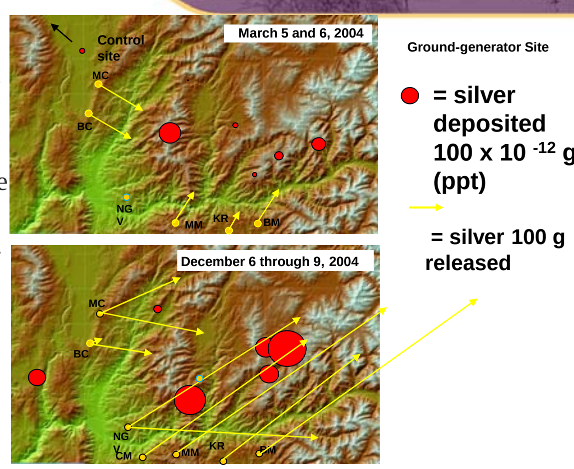
- Snow samples collected using ultra-trace 'metal clean' techniques and acid cleaned equipment.

Analytical Methods

- Samples acidified with ultra-pure nitric acid in class 100 clean room.
- Analysis by High Resolution Inductively Coupled Plasma Mass Spectrometry.
- Detection limits of ~ 300 parts per quadrillion for silver
  - 300 / 1,000,000,000,000,000 (10^{15})
- Think of it as a single drop of water in a cube 368m on a side or in a sports arena like the Idaho Center (Nampa, ID), or 5 minutes out of 31.7 million years.

Targeting from Chemistry Data

- Targeting of the seeding operations was assessed by integrating the silver found in the snow over a given storm period to estimate the total amount of silver deposited during the storm.



Example Targeting Maps for the March 2004 and December 2004 storm periods

Targeting Results

- The amount of silver deposited downwind of active ground generators was much greater than that found at the control sites.
- Silver distributions show that targeting was effective.
- Indium concentrations were generally very low
  - Silver not from scavenging
- Evidence for targeting by aircraft was found in the target area
- The project layout and operations can effectively hit the target area with **both** ground generators and aircraft.

Trace Chemistry Summary

- Snowpack conditions during assessment were 74% and 65% of normal (lack of storms limited seeding opportunities).
- During 2004-2005, DRI concluded cloud seeding revealed an overall average increase of 7%. Individual storm events ranged between 7% and 35% increases.
- Under favorable conditions, greater increases may be obtained through longer and more frequent seeding periods.
- Moving to flares significantly increases seeding potential from the aircraft.

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Downwind Effects

- Research on the subject has shown there are neutral or positive effects (more precipitation) from a **well run** program
- A poorly run program has the potential to reduce precipitation
- To put quantities into context…
  - Nature will condense about 20% of the water vapor as moist air rises over a mountain barrier (the remaining 80% remains uncondensed).
  - Winter storms are typically about 30% efficient, meaning 30% of the 20%, or 6% of the total, reaches the ground.
  - If cloud seeding increases precipitation 15%, that amounts to 15% of the 6%, or 0.9% of the total water vapor is the additional amount cloud seeding pulls from the atmosphere.

Silver Toxicity

- The WMA has issued a statement on toxicity of silver originating from cloud seeding… http://weathermodification.org/AGI_toxicity.pdf
- In summary,

  "The published scientific literature clearly shows ***no environmentally harmful effects*** *arising from cloud seeding with silver iodide aerosols have been observed; nor would they be expected to occur. Based on this work, the WMA finds that silver iodide is environmentally safe as it is currently being dispensed during cloud seeding programs."*

IDEQ Review

- IDEQ reviewed cloud seeding w.r.t. water and air quality.
- Water quality - it is unlikely that cloud seeding will cause a detectable increase in silver concentrations in target area or pose a chronic effect to sensitive aquatic organisms.
- Air quality permit not needed based on screening thresholds.

- http://www.idwr.idaho.gov/waterboard/WaterPlanning/CAMP/ESPA/WorkingGroups/PDF/WM//2010/02-09-10_MtgPresent.pdf

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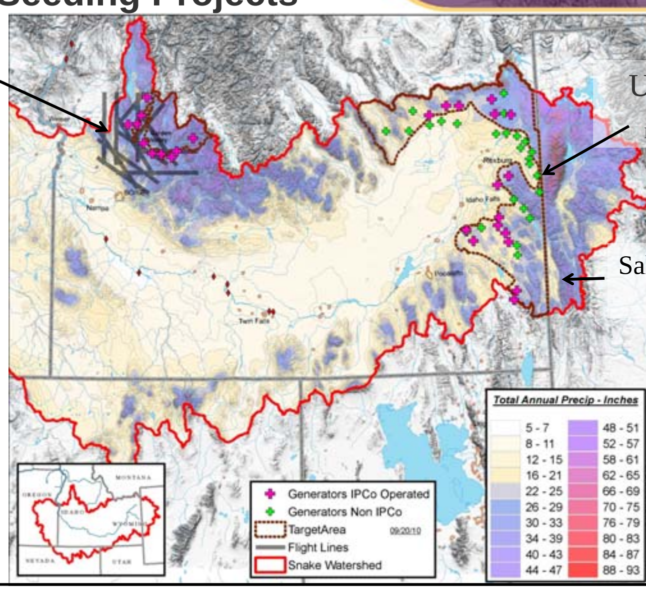
Idaho Power's History with Cloud Seeding

- At the request of shareholders – began investigating cloud seeding in 1993
- Literature review 1993 and 1994
- Climatology study 1994-95
- Contracted operational program in 1996-97
- Planned to perform internal program in 1997-98
  - canceled do to no mechanism to recover project expenses and share benefits
- Reinstated in Feb 2003.
- Operational including assessment in fall of 2003
- Completed second year of assessment and third year of operations in May 2005.
- In 2008 worked with HCRC&D and E Idaho Counties to enhance their program
  - In 2008 installed 3 remote generators, provided meteorological data and operations guidance
  - In 2009 installed 6 additional remote generators (total of 9)
  - In 2010 installing 7 additional generators for HCRC&D program (total of 16)
  - Purchasing data collection equipment and working with NCAR for a Phase II feasibility study for a project in Salt and Wyoming ranges.

Effective Program Includes

- Knowledge of:
  - Storm timing – prepare for operations
  - Water content – is the storm conducive to seed?
  - Temperature profile
  - Wind speed and direction
    - The wrong combination of temperature and water content can easily lead to reduced precipitation.
    - Winds effect targeting
- Operating Criteria
- Flexibility – ability to seed a range of conditions
- Aircraft safety
  - Flying a plane in storm conditions – pilot needs guidance regarding severe ice, lightning, etc.
- Suspension Criteria

Idaho Power's Cloud Seeding Projects



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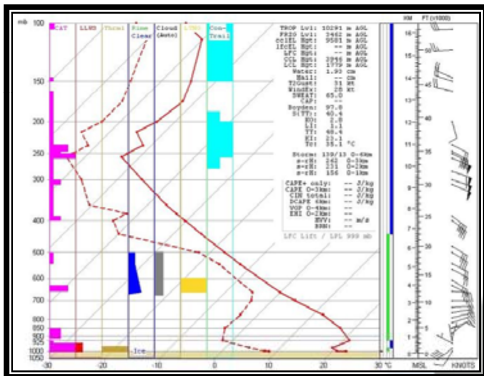
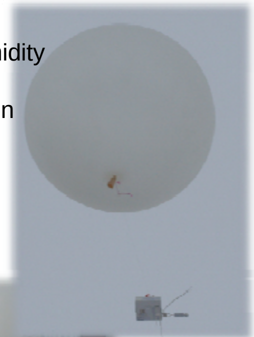
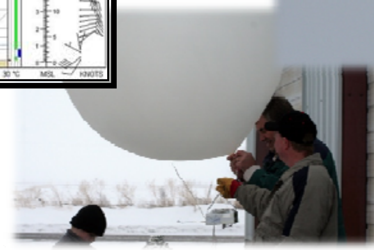


Temperature
Relative Humidity
Pressure
Wind Direction
Wind Speed

Up to 60,000’





Radiometrics M3000A

Microwave Radiometer

- Radiometers measure the power radiated by the atmosphere at different wave lengths. They are passive, receive-only instruments, meaning they emit no radiation themselves.
- The wave length of the radiation identifies the source of the emission resulting in a atmospheric profile:
  - Temperature
  - Relative Humidity
  - Liquid Water

IPC’s MP-3000A Hyper-Spectral Temperature, Humidity and Liquid Water Profiler.

Radiometer Data

- Real time atmospheric profiling by elevation:
  - Temperature
  - Relative Humidity
  - Liquid Water
  - Vapor Density

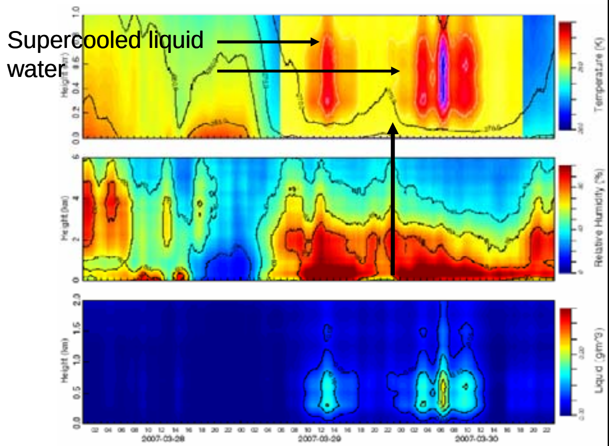
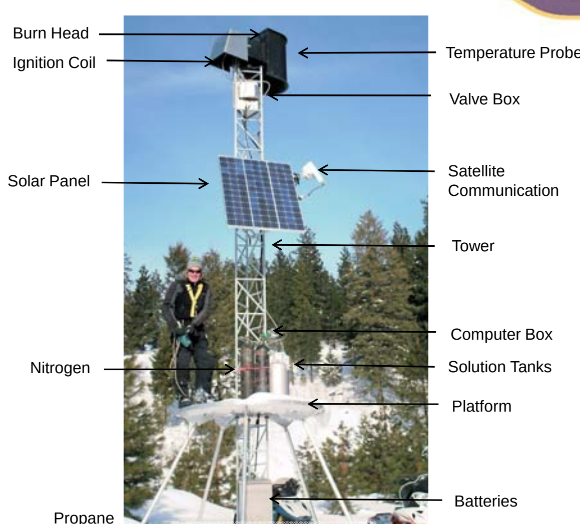


Image courtesy of Radiometrics

Generator Types



Remote Cloud Seeding Generator

Manual Cloud Seeding Generator

Aircraft Seeding

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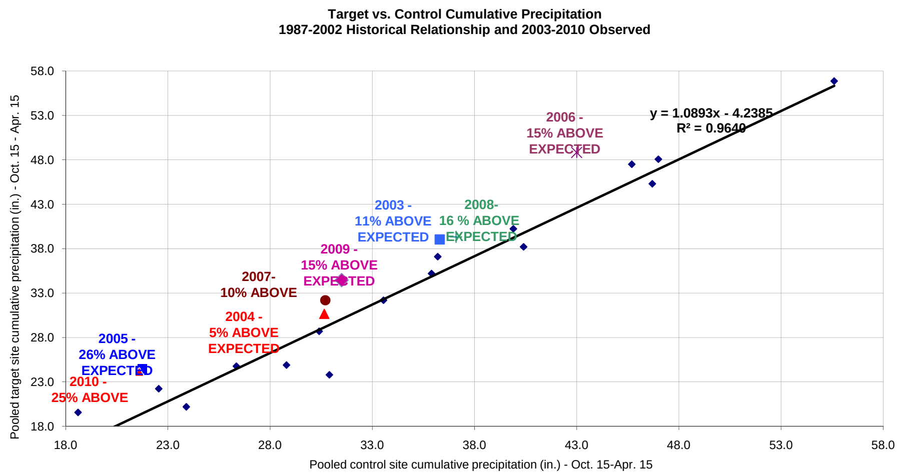
- Benefits

Target – Control
Payette



Operations Summary
Payette

Water Year	(April-July) % Normal*	% TC** Benefit	Silver Iodide (grams) Total	Air	Ground	Hours Air	Ground	Status
2003	93%	16%	33558	23270	10288	15.4	515	start-up (Feb-April)
2004	74%	5%	21485	2803	18682	11.9	930	assessment
2005	65%	25% / 7%***	27301	11122	16179	50.5	810	assessment
2006	136%	15%	113173	97710	15463	48.5	768	operational
2007	56%	10%	106082	76980	29102	51.3	1351	operational
2008	105%	16%	61147	38740	22407	29.4	1123	operational
2009	91%	15%	50274	26110	24164	17.1	1208	operational
2010	89%	25%	49823	30090	19733	17	987	operational

* Unregulated Payette Apr-Jul volume at Horseshoe Bend '71-'00 (USBR)
** TC = Target Control
*** DRI Trace chemistry average benefit
Seeding Summary All Years_10.xlsx

Benefit Estimation
Payette

- IPC has used 3 approaches to assess benefits since DRI's assessment:

1. USBR Run-off regression equations
2. Streamflow comparison
3. Watershed modeling using IPCRFS forecasting model

USBR Regression

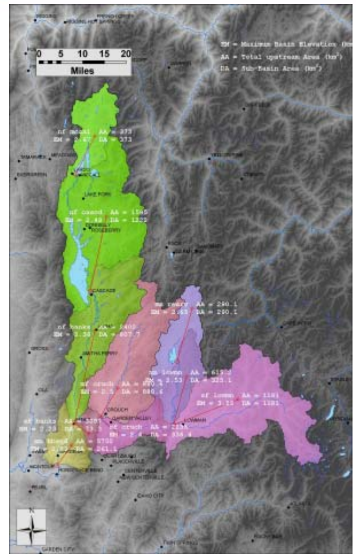
- USBR Equations use precipitation and SWE as input to predict runoff at specific locations.
- Target control analysis indicates precipitation increases ranging from 5% to 16% (average over 6 years of 13%*).
- Assuming a precipitation increase of 10% from cloud seeding results in an average of approximately **120 KAF** of additional April – July runoff at Horseshoe Bend.

*dropped highs from dry years. Retaining all years is a 16%.

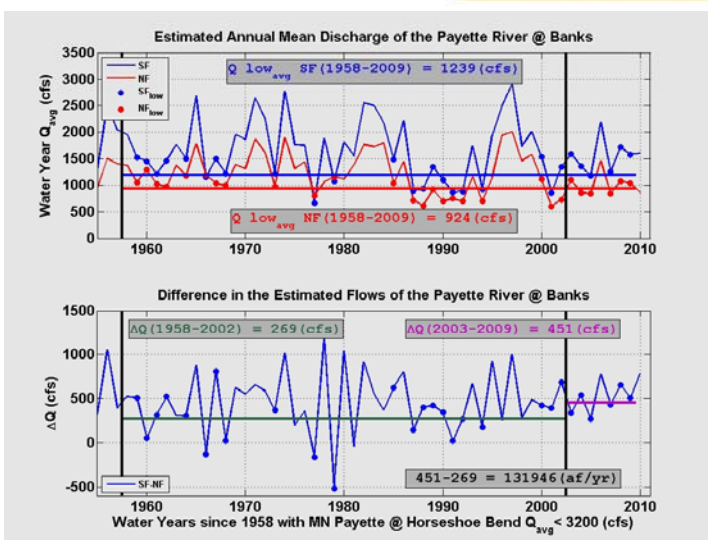
Run-off Comparison

- After running the program for a number of years, a comparison of streamflows was possible.
- By comparing streamflows, no analysis or assumptions regarding precipitation increases are necessary.
- Relative to the NF Payette, streamflows in the SF Payette have increased an average of **130 KAF** per year.
- Average precipitation increase of **9%**.

PRELIMINARY

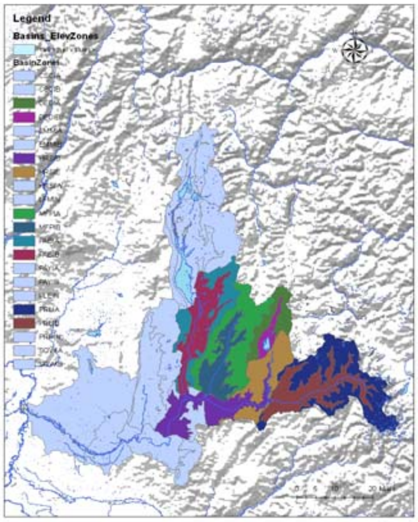


Run-off Comparison



Streamflow Modeling

IPC River Forecast System



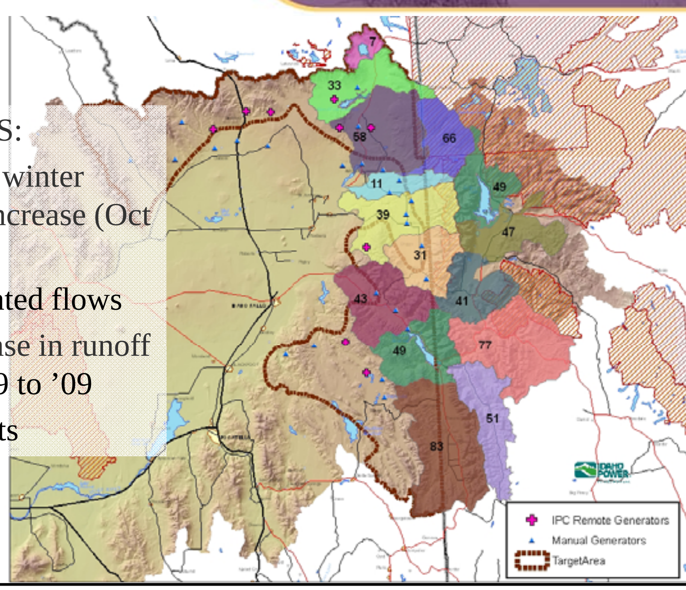
- Additional runoff estimated using IPC's NWS river forecast model.
- Model uses mean aerial temperature and precipitation (MAT & MAP) by elevation
- Two scenarios…with and without cloud seeding
- Without seeding – adjusted MAP down by amounts indicated by target-control analysis (observed data includes seeding)
- With seeding – used MAP based on observed data
- Streamflow increase nearly **200 KAF / year**

Cost: $4.25 - $7.00/AF

Upper Snake Potential

Using the IPCRFS:

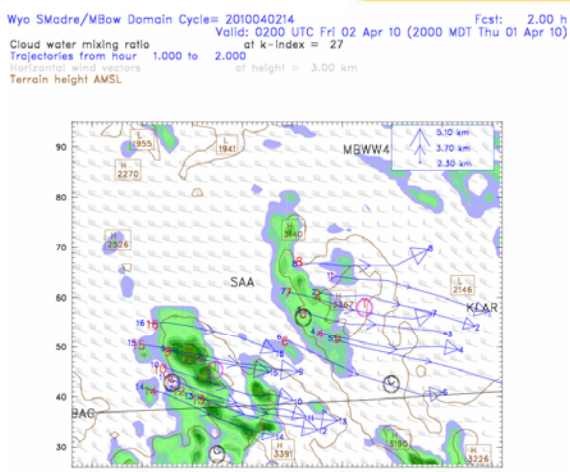
- Assumes 10% winter precipitation increase (Oct – Mar)
- Local unregulated flows
- Average increase in runoff over period '49 to '09
- DRAFT Results



Upper Snake Opportunities

- IPC will have 16 remote generators in upper Snake this winter.
- Conduct Phase II feasibility study in Salt and Grays drainages.
  - Data collection – weather balloons, radiometer, weather station
  - Modeling evaluation with NCAR

Example Modeling Results



WRF-RTFDDA Trajectory/Cloud Water Map (2 April 2010)

Questions?