RECLAMATION

Managing Water in the West

75 Years of Hydraulic Modeling – Fueling Technical Innovation in Reclamation

U.S. Department of the Interior
Bureau of Reclamation

History begins…….

- Reclamation Act, signed by President Roosevelt in June 1902.
  - Authorized construction of irrigation projects in 14 western states and two territories (Arizona and New Mexico). Congress added Texas in 1906.
- July 1902, the United States Reclamation Service was established within the U.S. Geological Survey.
  - Charles D. Walcott was the first Director and Frederick Newell became Chief Engineer.
- The USRS continued studies of potential reclamation projects begun by the USGS as early as 1889.

Early Projects

- From 1902-1907, Reclamation began about 30 projects in the Western states.
- In 1907, the Secretary of the Interior separated the Reclamation Service from the USGS, creating an independent Bureau within Interior.
- Many large dams were designed and constructed in these early years; including, Shoshone, Roosevelt, Pathfinder, Arrowrock, Elephant Butte, Minidoka, Lahontan, Belle Fourche, and Jackson Lake.
- The plans to build a very large dam on the Colorado River – Boulder Dam - led Reclamation to establish a hydraulic lab for studying the many new problems they would face with this structure.

First Reclamation Hydraulics Lab Established in August 1930.

- Staff of 12 engineers, carpenters, and laborers moved up to Ft. Collins and into the Colorado Agricultural Experimental Station.
- This lab had been established by Ralph Parshall in 1912-1913 on the campus of Colorado A & M College (now known as Colorado State University).

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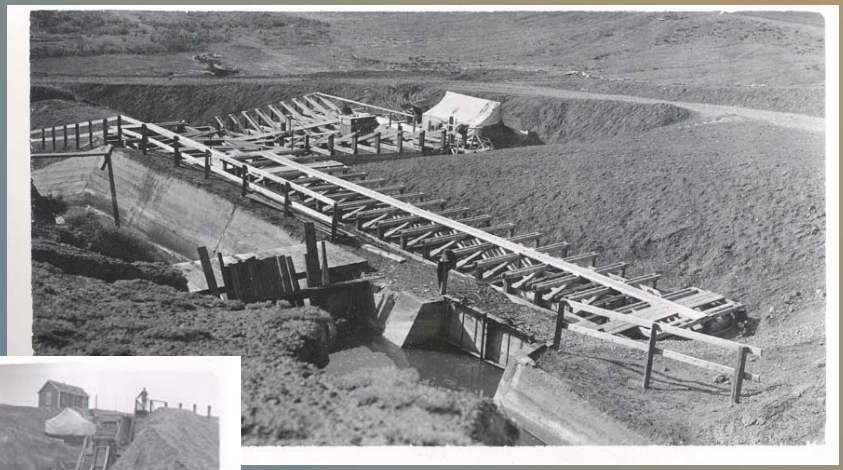
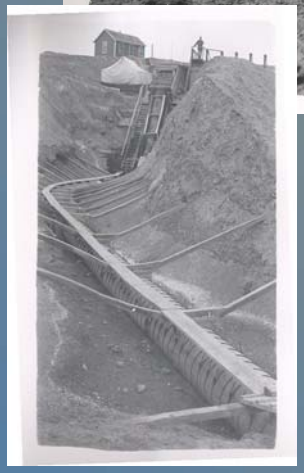
Montrose Field Laboratory

- During the summers between 1931 to 1936, an outdoor laboratory was operated on the South canal of the Uncompahgre Project, 8 miles east of Montrose, Colorado.
- The lab had a head of 50 ft and a discharge up to 200 ft^3/s available.





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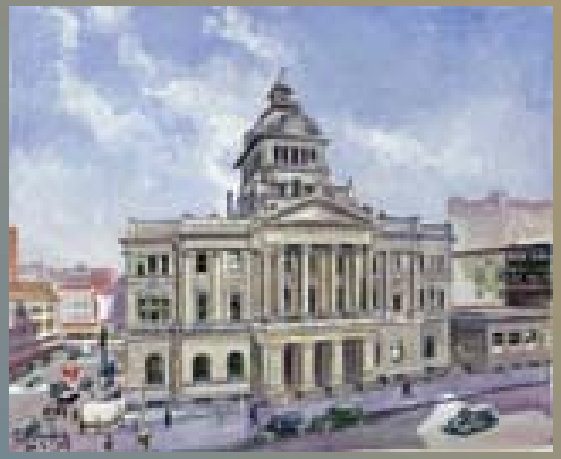
Lab established in the Old Customhouse

- Lab was established in the basement of the Old Customhouse in 1934.
- Reasoning for the move was predicated on the need to be closer to the designers so there could be more interaction.
- Many smaller scale models were studied here.
- Lab was operated at this location until 1937.



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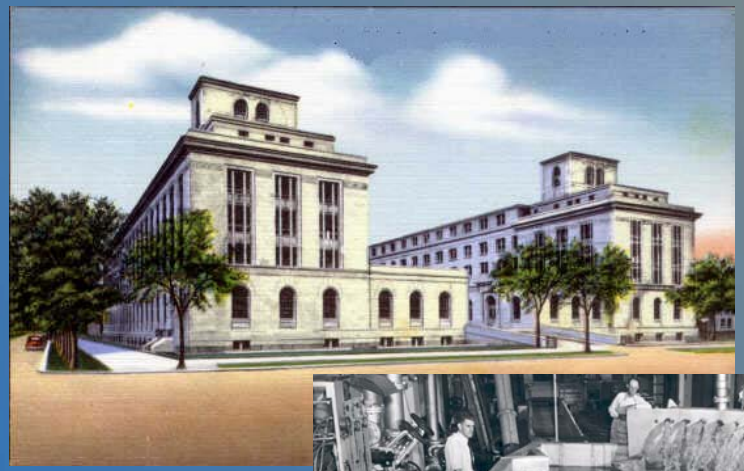
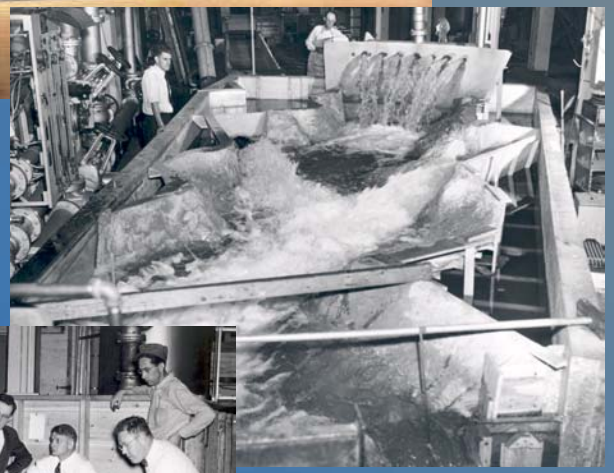
Move to the New Customhouse





- In 1937 when the addition to the New Customhouse was completed, Lab equipment and personnel moved to the site at 19th and Stout Street.
- Much more space was available, and the Reclamation personnel at the Ft. Collins Lab were gradually moved back to Denver.
- Reclamation discontinues operations in the Ft. Collins Lab in the fall of 1938.

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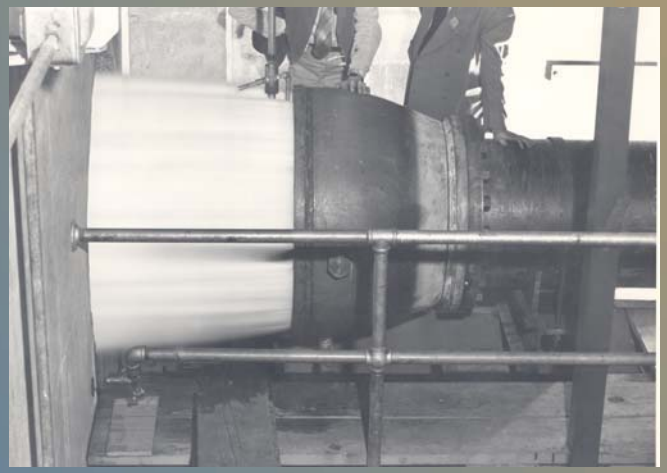
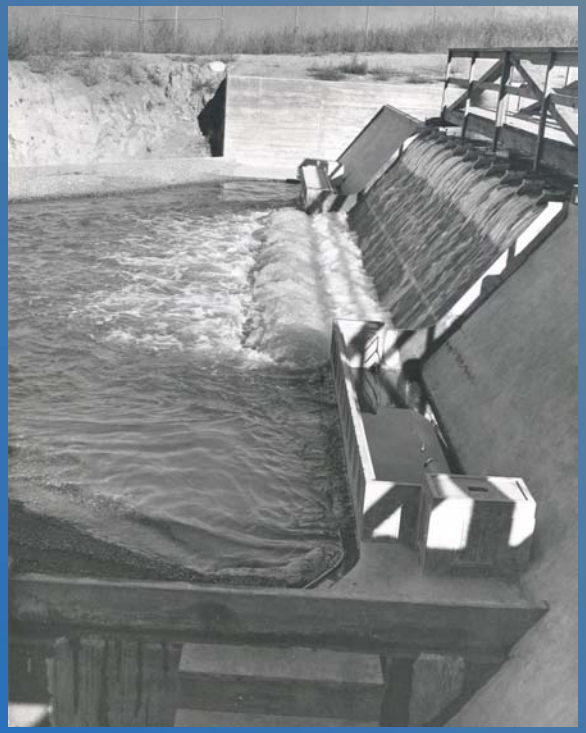
Other Field Laboratories

- A valve test stand was constructed in 1939 on the Arizona side – canyon wall outlet house at Boulder Dam.
- Allowed for high-head testing of new valve designs prior to installation.



Testing of a 24” model hollow-jet valve



- Vista Park Model at Grand Coulee Dam.
- A 1:60 scale model of the spillway was constructed in 1943.
- Became a display after completion of testing.

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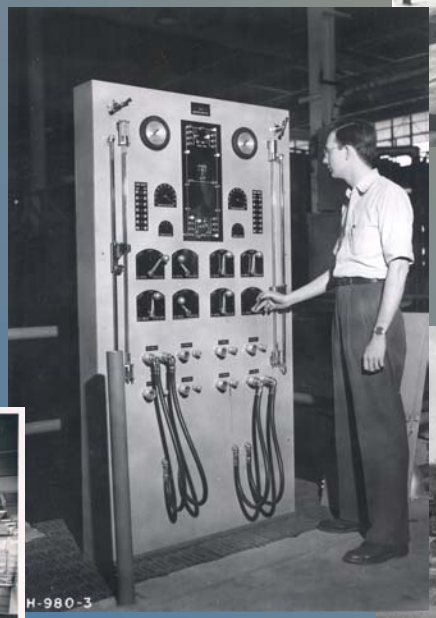
Laboratories make the move to the Denver Federal Center

- In the later part of 1946, the hydraulic laboratory moved to its present location in Bldg. 56 at the Denver Federal Center.
- Over the span of a couple of years, lab facilities were installed that were unequaled at that time, resulting in the largest indoor hydraulic lab in the world.



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Innovation

- Webster defines as: *a new idea, method, or device…*

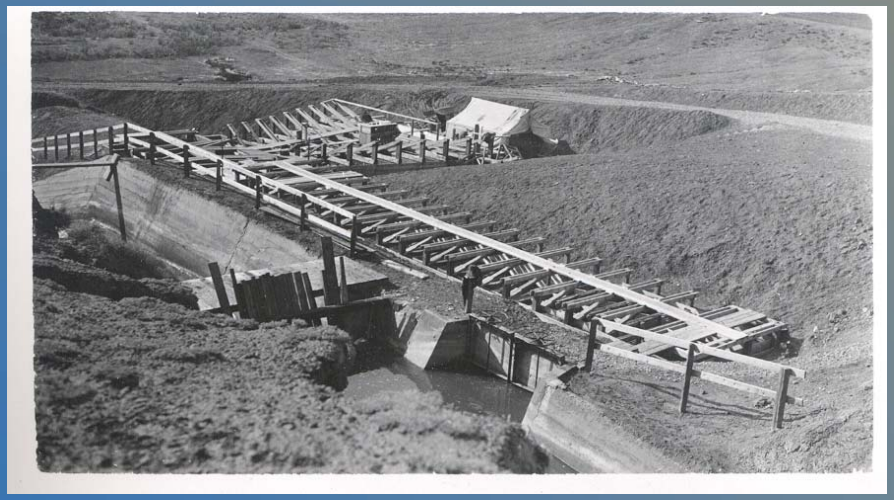
- The spillways for Boulder Dam was one of the first opportunities for innovation by the laboratory staff. During the course of the late 1920's and early 1930's, designers had been busily trying to layout and design a structure required to pass 400,000 ft^3/s, with a fall of 500 feet.
- The velocity of the water would reach 175 ft/s, considerably exceeding that of any similar structure previously considered.

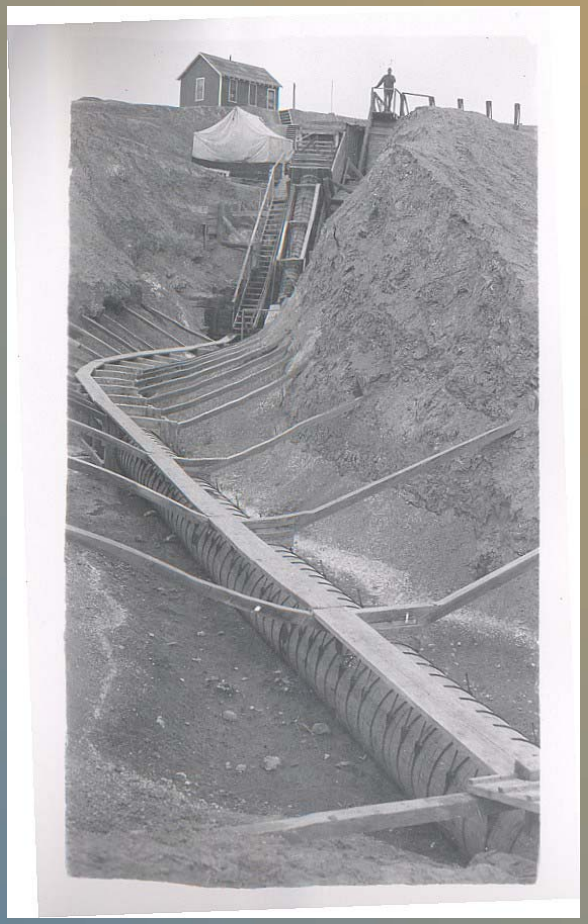
Boulder Dam Spillway models

- A morning-glory shaft spillway, 1:60 scale, designed for 100,000 ft^3/s.
- A side channel type without crest gates, 1:60 scale, designed for 140,000 ft^3/s.
- A side channel type with a Stoney gate at one end, 1:60 scale, designed for 200,000 ft^3/s.
- A side channel type with drum gates on the crest, 1:20 scale, designed for 200,000 ft^3/s.
- A modified side channel with drum gates on the crest, 1:60 scale and 1:20 scale, designed for 200,000 ft^3/s.

1:60 scale model of the Boulder Dam spillway in the Ft. Collins Lab

1:20 scale model of Boulder Dam spillway at the Montrose Lab





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Boulder Dam Spillway Models

- These models took the better part of two years of intensive work to complete (Oct. 1930 – April 1932).
- After all was said and done, a total of eleven models were tested, many of them with large numbers of variations, using geometric scales from 1:100 to 1:20.
- The use of tunnels to carry the large amounts of high-energy flow around the dam structure was an innovation of the time.
- Reclamation has used tunnel spillways at many other structures and they are still a viable alternative when designing a spillway today.

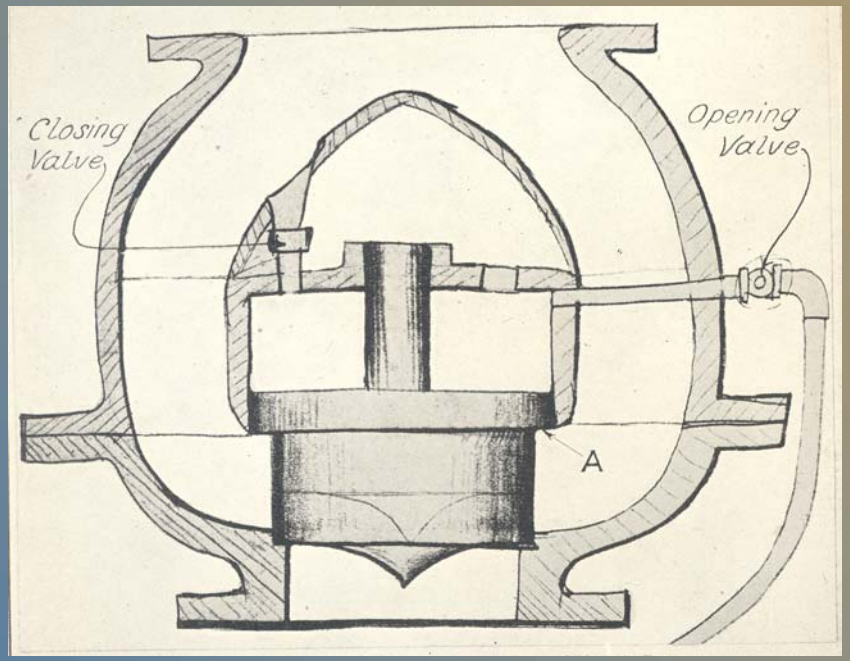
High-head gates and valves

- Once again innovation occurs with opportunity!

- Even before the beginnings of the laboratory, Reclamation engineers were making innovative designs become reality.
- Very little precedent existed for high-head outlet works of large capacities in the early 1900's.
- Close regulation of the flows from reservoirs had not been much of an issue.

The Ensign Valve

- By means of two clever refinements, the cylinder gate was made into the first needle-type valve to open and close by controlled manipulation of the water pressure from the reservoir.
- The design was credited to O.H. Ensign in 1906, then chief electrical engineer of the Bureau of Reclamation.
- A model was built and tested at Roosevelt Dam in 1906 that lead to the design and manufacturing of larger-sized valves.



Ensign's original sketch

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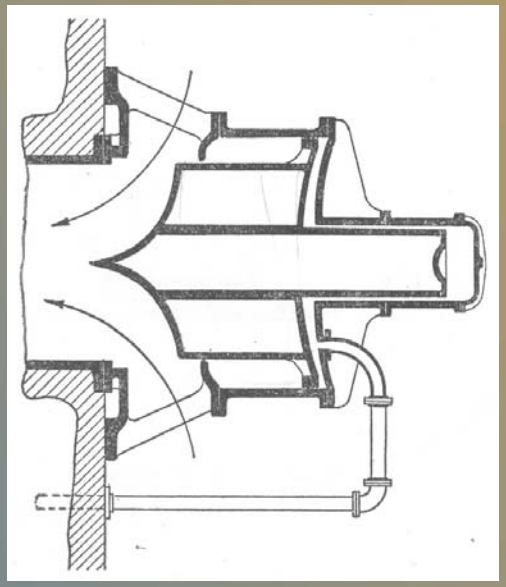
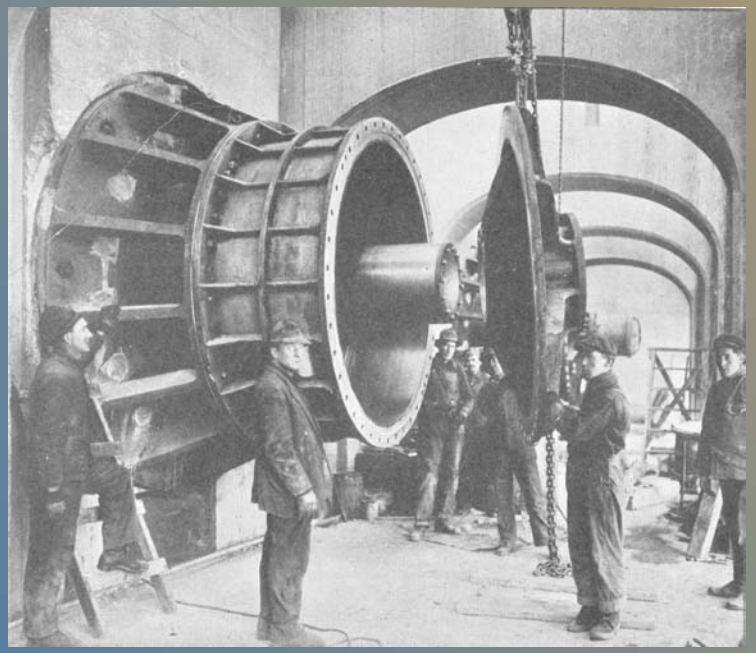
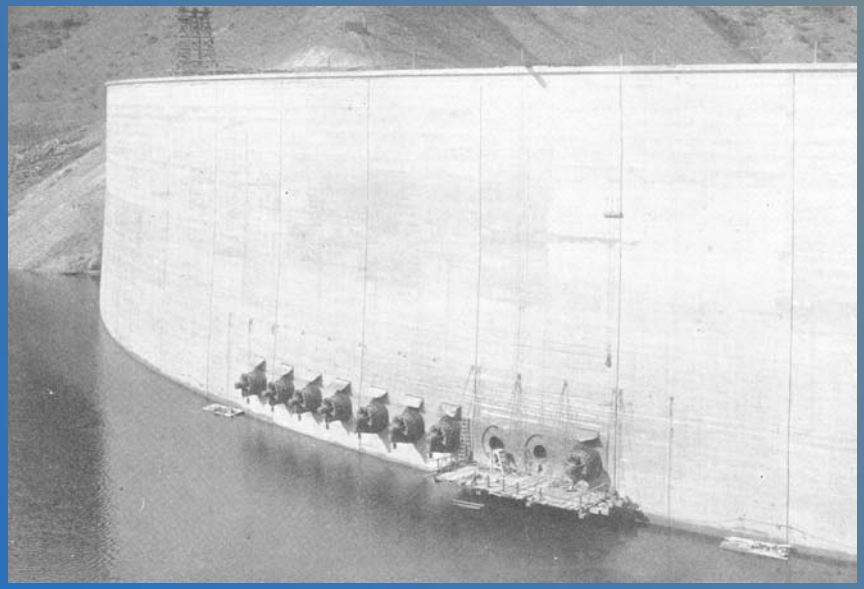
The Ensign Valve

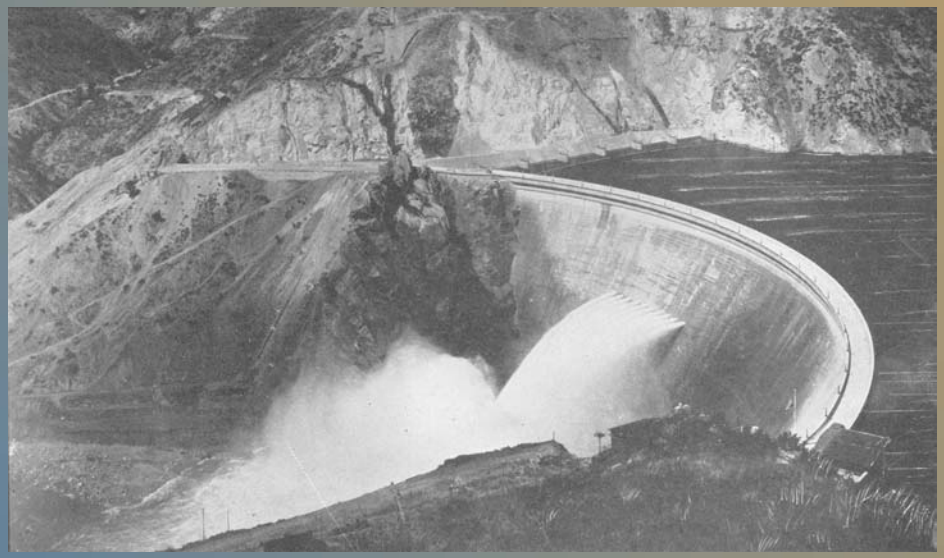
- The Ensign valve was usually mounted on the dam face – at the beginning of the conduit.
- It was used extensively in Reclamation's early high-head installations.
- Sometimes problems with closing the valve.
- Subject to creeping.
- Subject to cavitation damage





Arrowrock Dam





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High-head gates and valves

- Valve models were tested at various locations around Reclamation projects beginning in 1906 at Roosevelt Dam. Model tests continued for many years once the laboratory was established, both in the lab and at field sites.
- Over the next several decades, but especially in the period of the 1940's, many new innovative designs were modeled, tested, and prototypes built and installed.
- Although not met with the same opportunities as the engineers of the 1940's, recent improvements and innovation continues.

Reclamation design credits

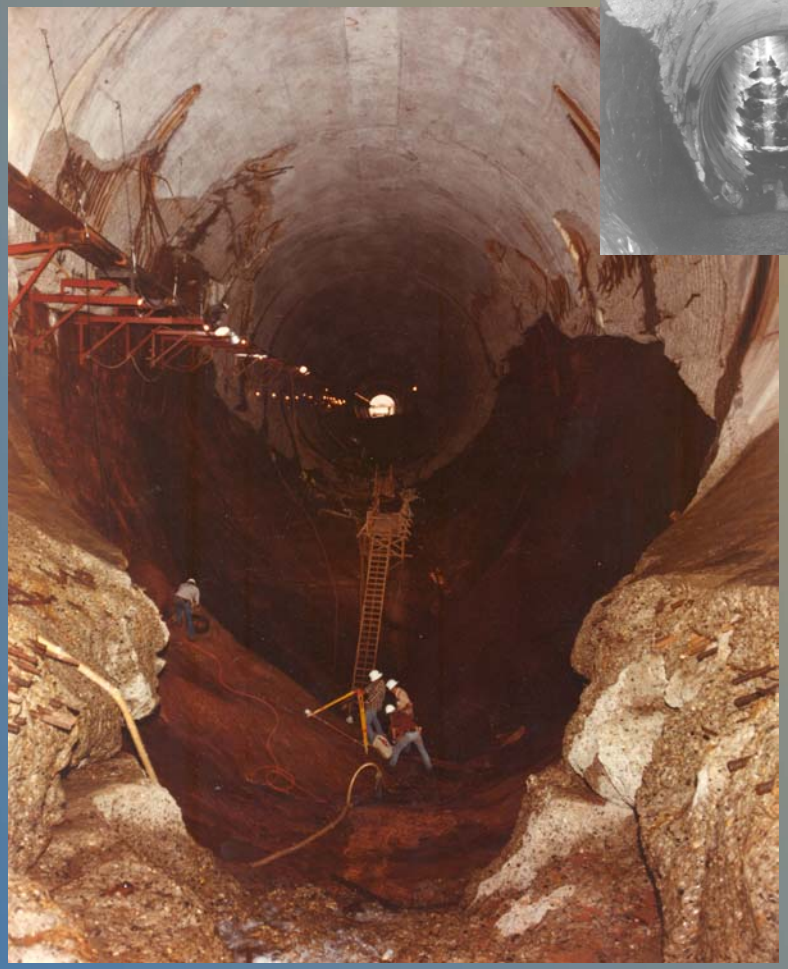
- Refined needle valve
- Tube valve
- Hollow-jet valve
- Hooded fixed-cone valve
- Jet-flow gate
- Multi-ported sleeve valves
- Clamshell gate

Arrowrock Dam

Aeration slots for tunnel spillways

Hoover – 1941

Yellowtail – 1967



Glen Canyon 1983

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Aeration slots for tunnel spillways

- Tunnel spillways were effective at moving the high-energy flow downstream, away from the dam's foundation; however, the profile of the spillway was subject to cavitation damage.
- Damage first occurred at Hoover Dam in 1941, the holes were filled and brought back to grade.
- When damage occurred at Yellowtail Dam in 1967, engineers realized they had a problem. It was cavitation and model studies ensued.

Air slots, cont.

- Prior lab studies had shown that even small amounts of air introduced into the flow would protect flow surfaces from cavitation damage (Peterka 1953).
- A ramp was devised to use the pressure difference created by forced separation with the boundary.
- Model studies guided the design and a prototype test measured the effectiveness. The fix was a success – once again opportunity sparks innovation.
- Damage was predicted at many of the other Reclamation tunnel spillways by lab experts, including Glen Canyon. In 1983 the critical flow conditions were achieved at Glen Canyon and substantial damage occurred.

Glen Canyon Aeration Slot

- Model studies were again used to refine the aeration ramp design, a massive construction program commenced to install the air slots. Flow tests after the installation proved the design was effective and it continues to protect the spillway from cavitation damage .

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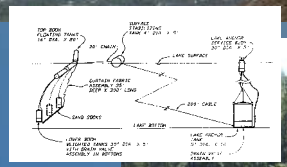
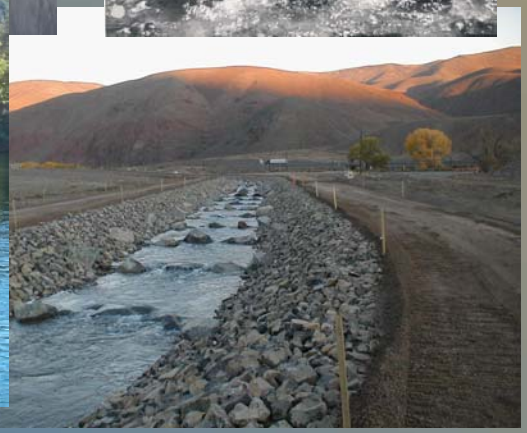
Innovations too numerous to mention…

- Energy dissipation structures
- Labyrinth weirs
- Fuse plug spillways
- RCC Stepped spillways and stepped overtopping protection.
- Reservoir curtains for selective withdrawal
- Fish passage and protection structures





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Closing….

- Reclamation engineers, and in particular those working in the hydraulic laboratory have had an incredible amount of opportunity to innovate.
- The art and science of large dam building and all the related issues that Reclamation has faced in their first 100 years of existence have provided those opportunities.
- Today as we move into an age of managing water in the West and maintaining our constructed infrastructure, the opportunities are still there for Reclamation, they just may not be “traditional”.
- Reclamation continues to be a leader in the world water resources arena. The challenges of a new day should provide many opportunities for innovation and we can only imagine what the future holds.
- Imagine what those engineers back in 1930 must have thought when faced with the daunting tasks ahead… *INNOVATION* lead them through that period and we can only hope we do as well in the next 75 years.