Environmental Issues Impacting Power Production in the Cumberland System

Bob Sneed

Water Management Section Chief

Nashville District Corps of Engineers

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US Army Corps of Engineers

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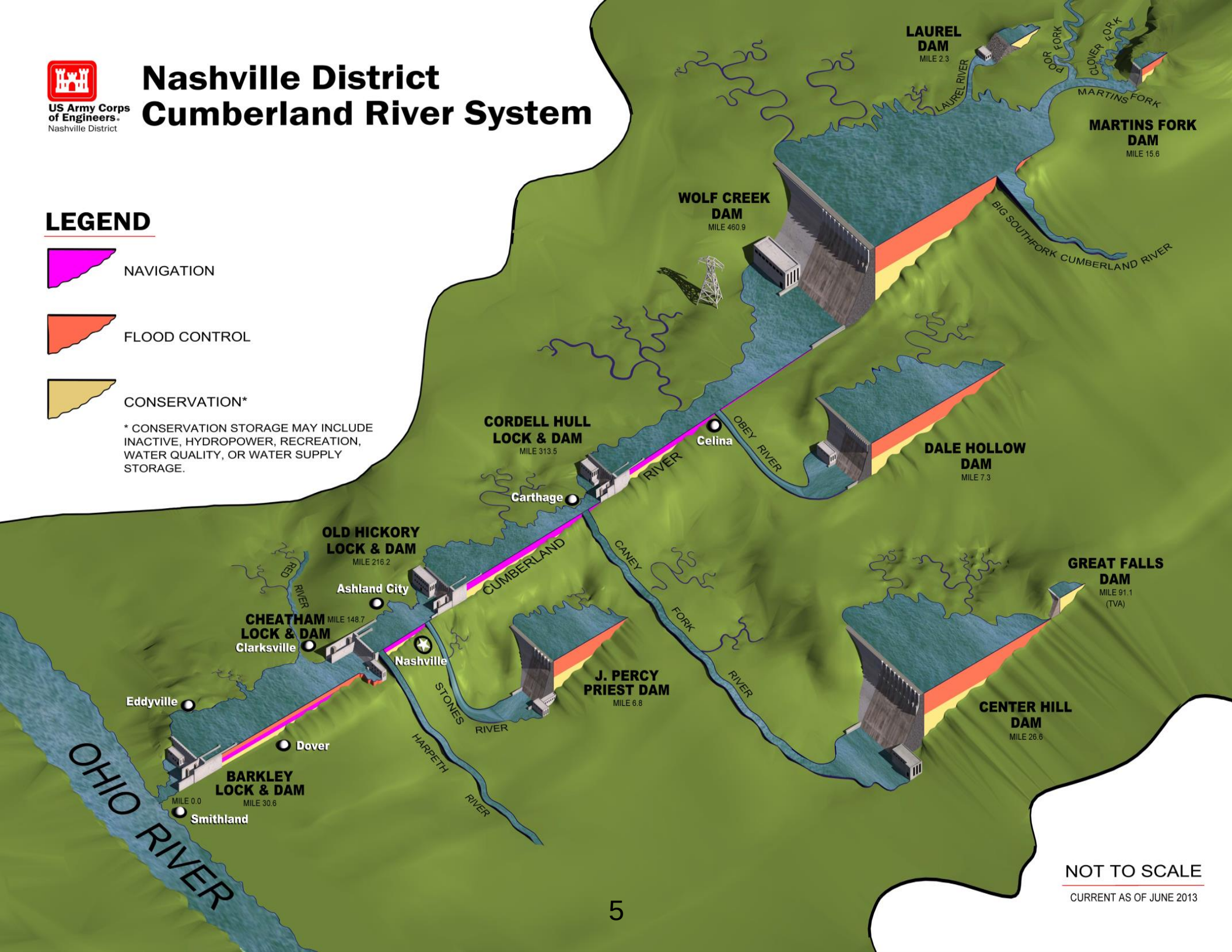
Purpose and Goal

- The purpose of this water management presentation is to provide information about:
  - ▶ Factors impacting water quality
  - ▶ Operational response to degraded water quality conditions
  - ▶ Physical modifications to Cumberland Basin projects
  - ▶ Benefits of auto-venting turbines
- Goal – provide you with an understanding of how degraded water quality conditions develop, their impact to hydropower generation, and how they are addressed through reservoir system operations and modifications to powerplant infrastructure.

Congressionally Authorized Project Purposes

Project	Flood Damage Reduction	Commercial Navigation	Hydropower	Recreation	Water Quality
Martins Fork Dam					
Laurel Dam					
Wolf Creek Dam					
Dale Hollow Dam					
Center Hill Dam					
J. Percy Priest Dam					
Cordell Hull Lock & Dam					
Old Hickory Lock & Dam					
Cheatham Lock & Dam					
Barkley Lock & Dam					

Project not designed for this purpose	
Project designed for this purpose	


US Army Corps of Engineers
Nashville District
Nashville District
Cumberland River System
LEGEND
NAVIGATION
FLOOD CONTROL
CONSERVATION*
* CONSERVATION STORAGE MAY INCLUDE INACTIVE, HYDROPOWER, RECREATION, WATER QUALITY, OR WATER SUPPLY STORAGE.
LAUREL DAM
MILE 2.3
LAUREL RIVER
POOR FORK
CLOVER FORK
MARTINS FORK
MARTINS FORK DAM
MILE 15.6
WOLF CREEK DAM
MILE 460.9
BIG SOUTHFORK CUMBERLAND RIVER
CORDELL HULL LOCK & DAM
MILE 313.5
Celina
OBEY RIVER
DALE HOLLOW DAM
MILE 7.3
Carthage
CUMBERLAND RIVER
OLD HICKORY LOCK & DAM
MILE 216.2
RED RIVER
Ashland City
CHEATHAM LOCK & DAM
MILE 148.7
Clarksville
Nashville
CANEY FORK RIVER
GREAT FALLS DAM
MILE 91.1
(TVA)
J. PERCY PRIEST DAM
MILE 6.8
STONES RIVER
CENTER HILL DAM
MILE 26.6
Eddyville
Dover
HARPETH RIVER
BARKLEY LOCK & DAM
MILE 30.6
MILE 0.0
Smithland
OHIO RIVER
NOT TO SCALE
CURRENT AS OF JUNE 2013

The Water Management Challenge

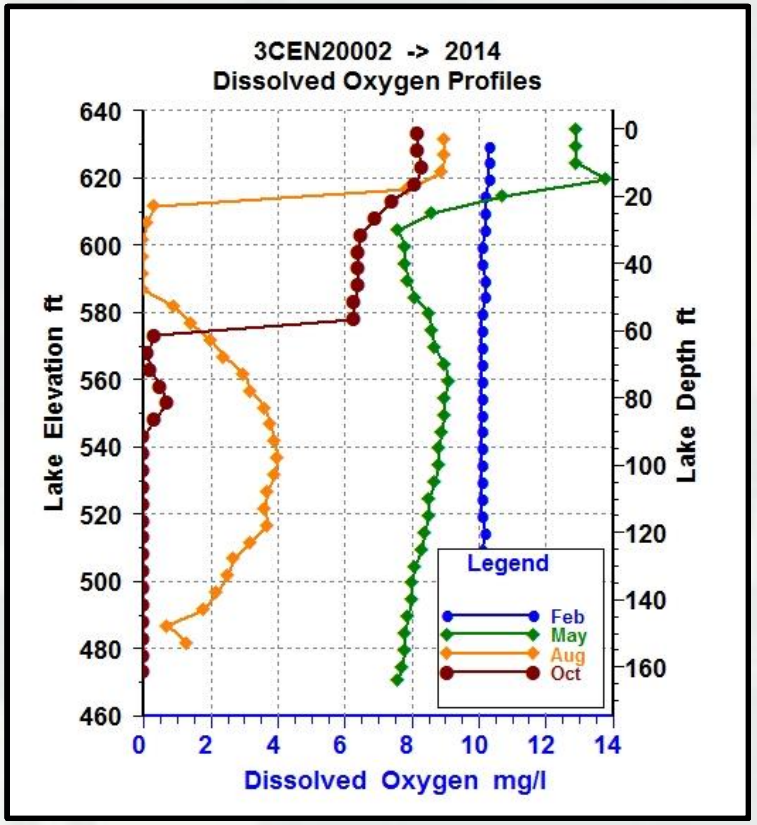
- Water Control
  - Flood
  - Drought
- Water Quality
  - Water Temperature
  - Dissolved Oxygen
- Project Authorized Purposes
- Environmental Statutes
- Balancing Act

Water Management Team

- Nashville District Water Management
  - Multidisciplinary staff – engineers & scientists
  - Perform complete system analysis every day
- Nashville District Hydropower Operators
  - 24/7 operational support
- Great Lakes & Ohio River Water Management
  - Ohio/Mississippi flood control operations
  - Program oversight
- Federal Partners
  - Tennessee Valley Authority (TVA)
  - National Weather Service
  - U. S. Geological Survey
  - Southeastern Power Administration (SEPA)

Thermal Stratification

- Annual Cycle
  - Water column completely mixed in winter
  - Surface water warms in spring resulting in density based layers in the water column
    - Epilimnion – warm, oxygenated surface zone
    - Metalimnion – transition zone (thermocline)
    - Hypolimnion – cold zone where oxygen becomes depleted
  - Stratification intensifies in summer
  - Mixing process starts in the fall when temperatures drop (happening now)
- More severe at storage projects
- Results in low dissolved oxygen (DO) concentrations in hydropower releases



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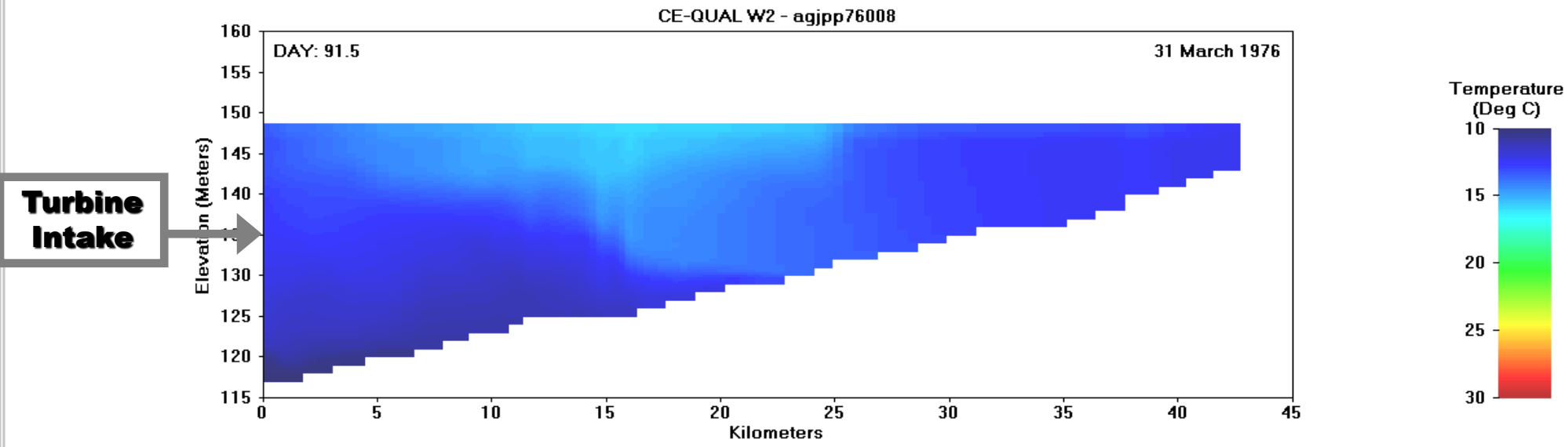

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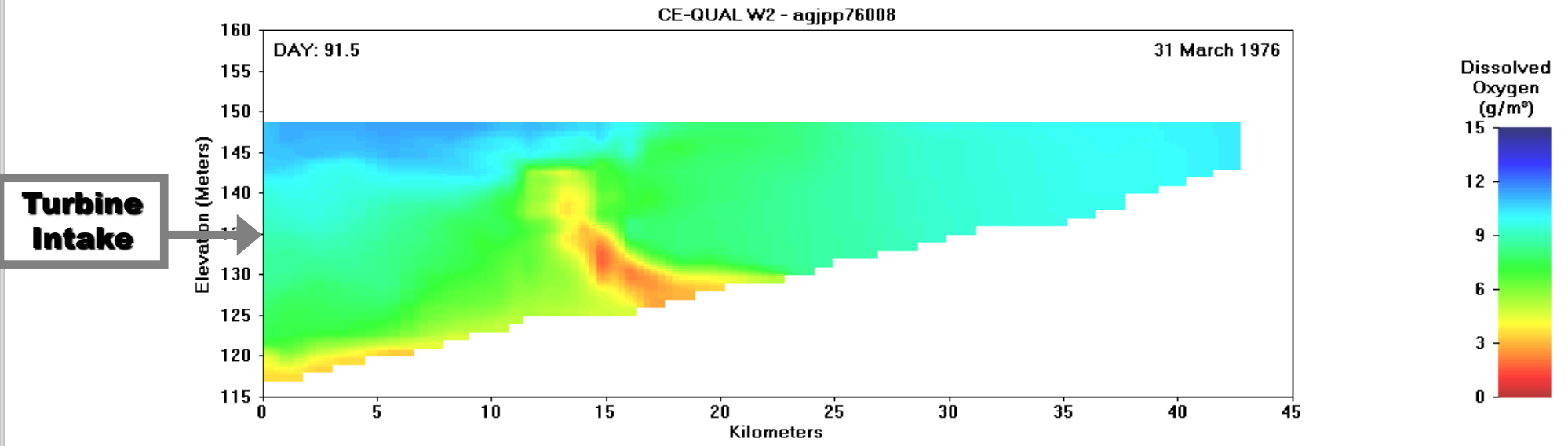
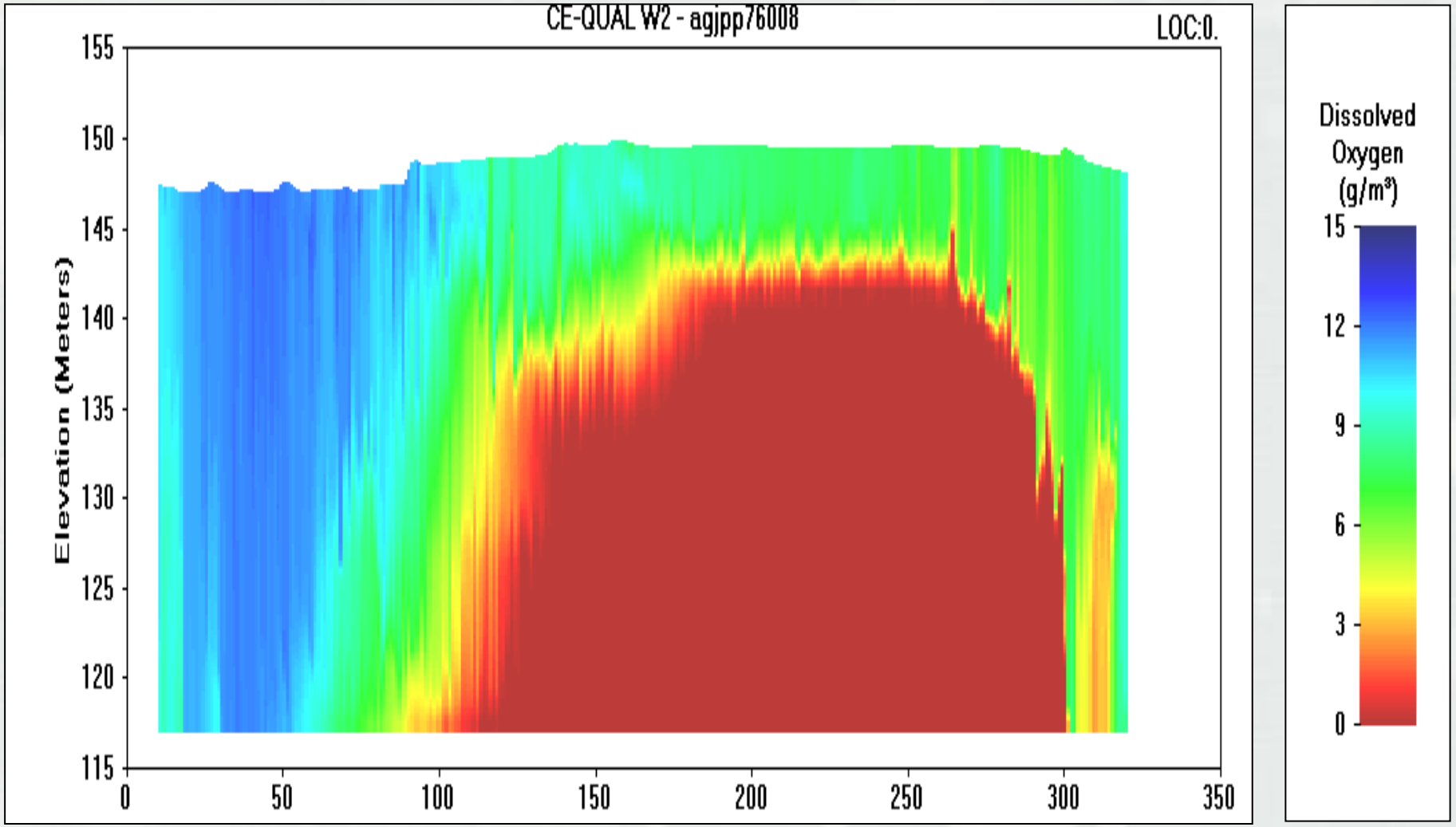


J. Percy Priest Dam
Forebay Dissolved Oxygen Distribution

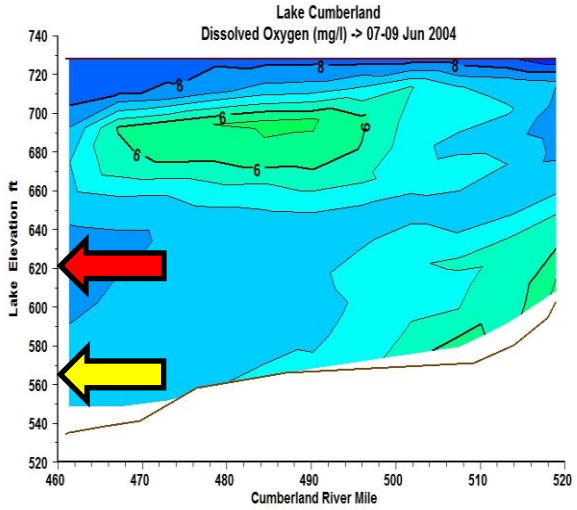


General Water Quality Trends

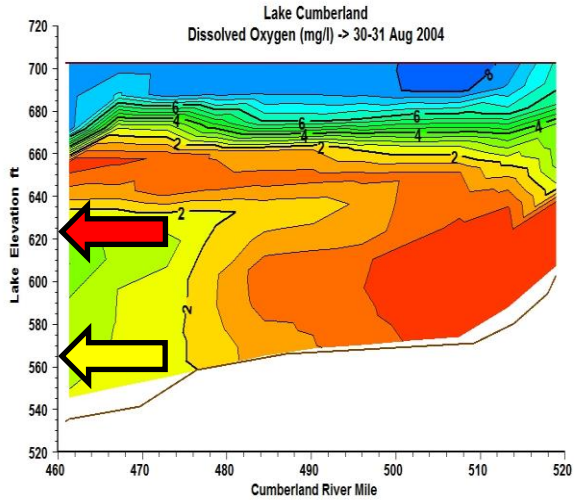
- **Wet Years**
  - Good water quality conditions along the Cumberland River main-stem
    - Releases from storage projects high enough to maintain good temperature and DO conditions
    - Old Hickory release is the control point
    - Hydropower and water quality flow requirements are compatible
  - Temperature and DO conditions not good from storage projects
    - Volume of cold, oxygenated water can be exhausted
- **Dry Years**
  - Water quality challenges experienced along the main-stem
    - Not enough cold, oxygenated water in storage to meet DO standard
    - Can lead to cooling water issues at Gallatin and Cumberland City steam plants
- **“Normal” Years**
  - Main-stem project releases ok
  - Some low DO values observed in tributary project releases
    - Center Hill and Wolf Creek releases fall below standard
    - Water quality in J. Percy Priest releases becomes poor in May regardless of hydrologic conditions

Lake Cumberland Dissolved Oxygen (mg/l) Longitudinal Profiles – 2004 & 2014

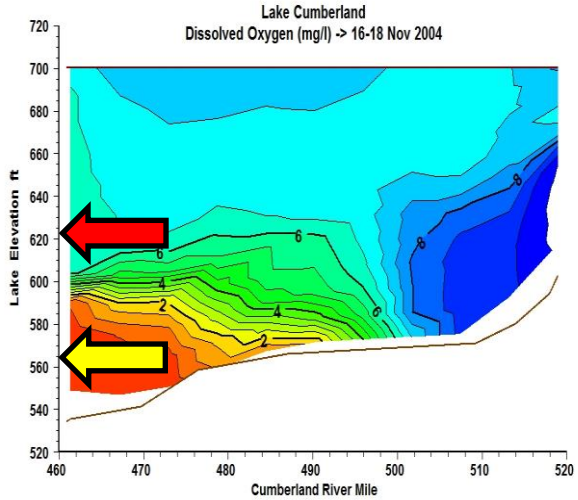
June 2004



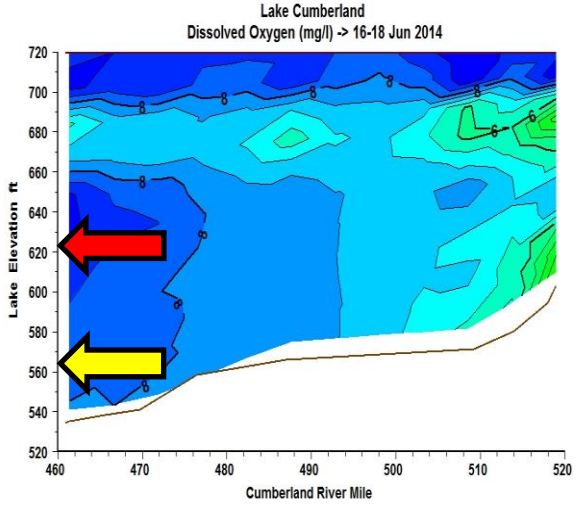
August 2004



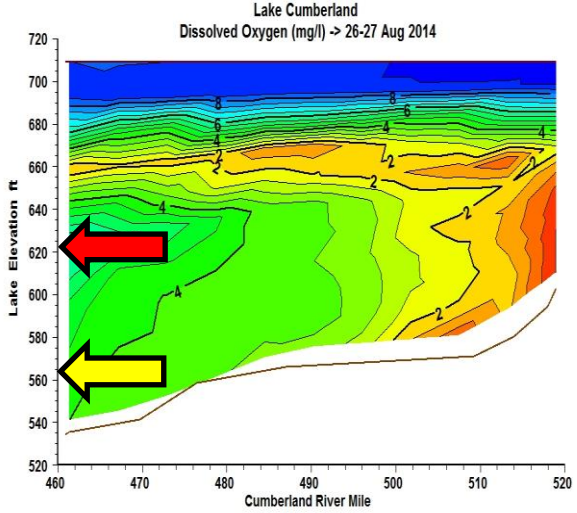
November 2004



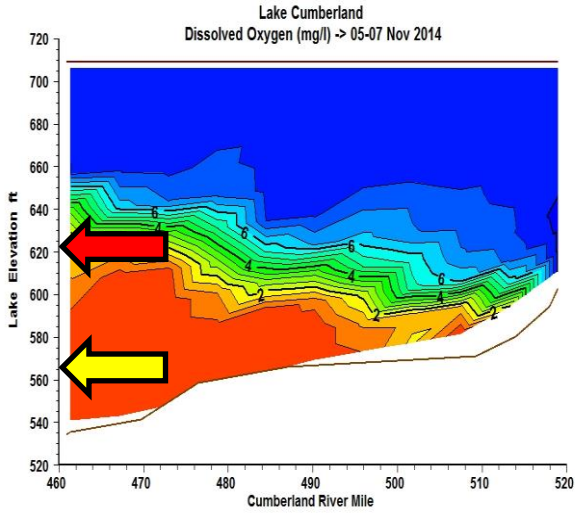
June 2014



August 2014

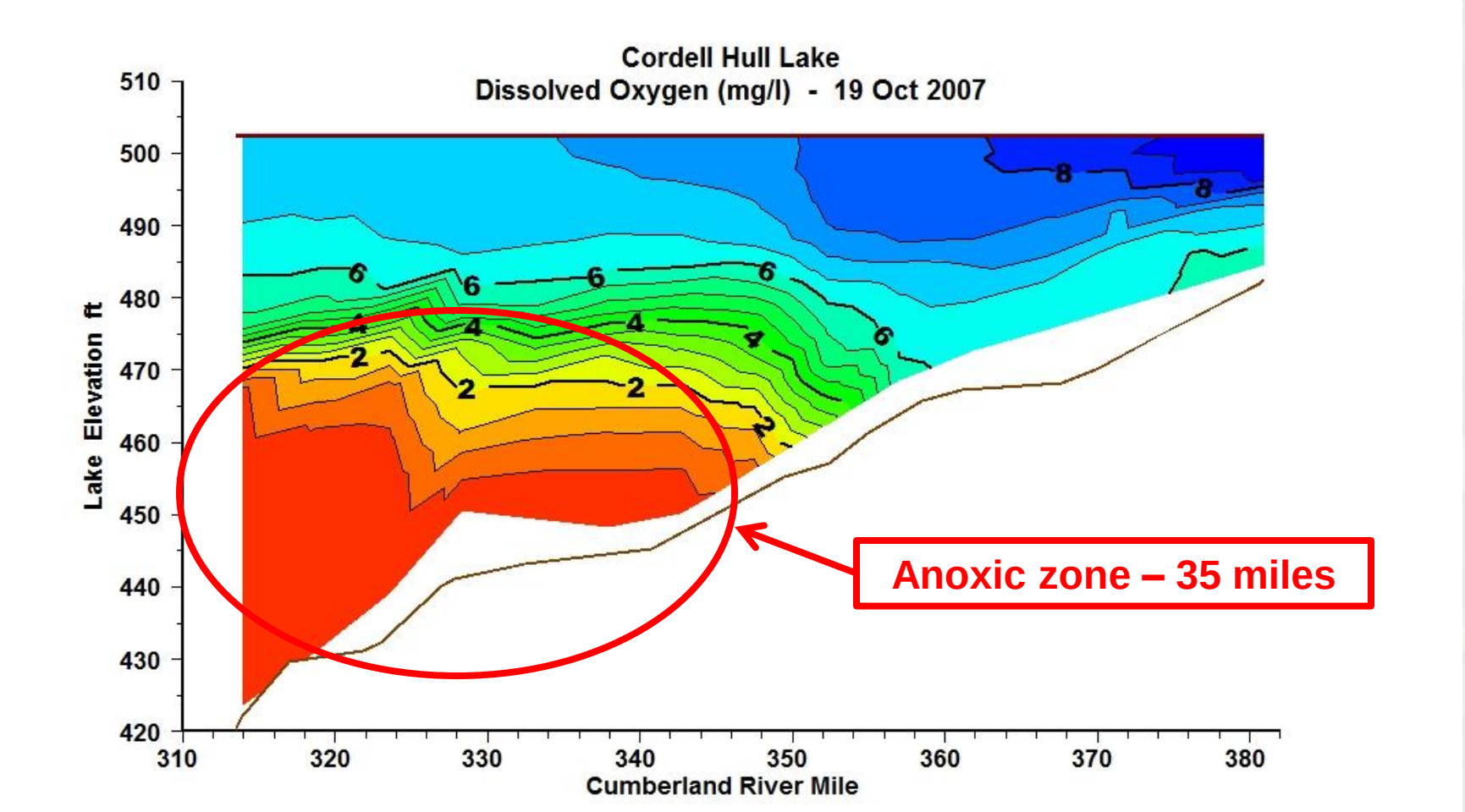


November 2014

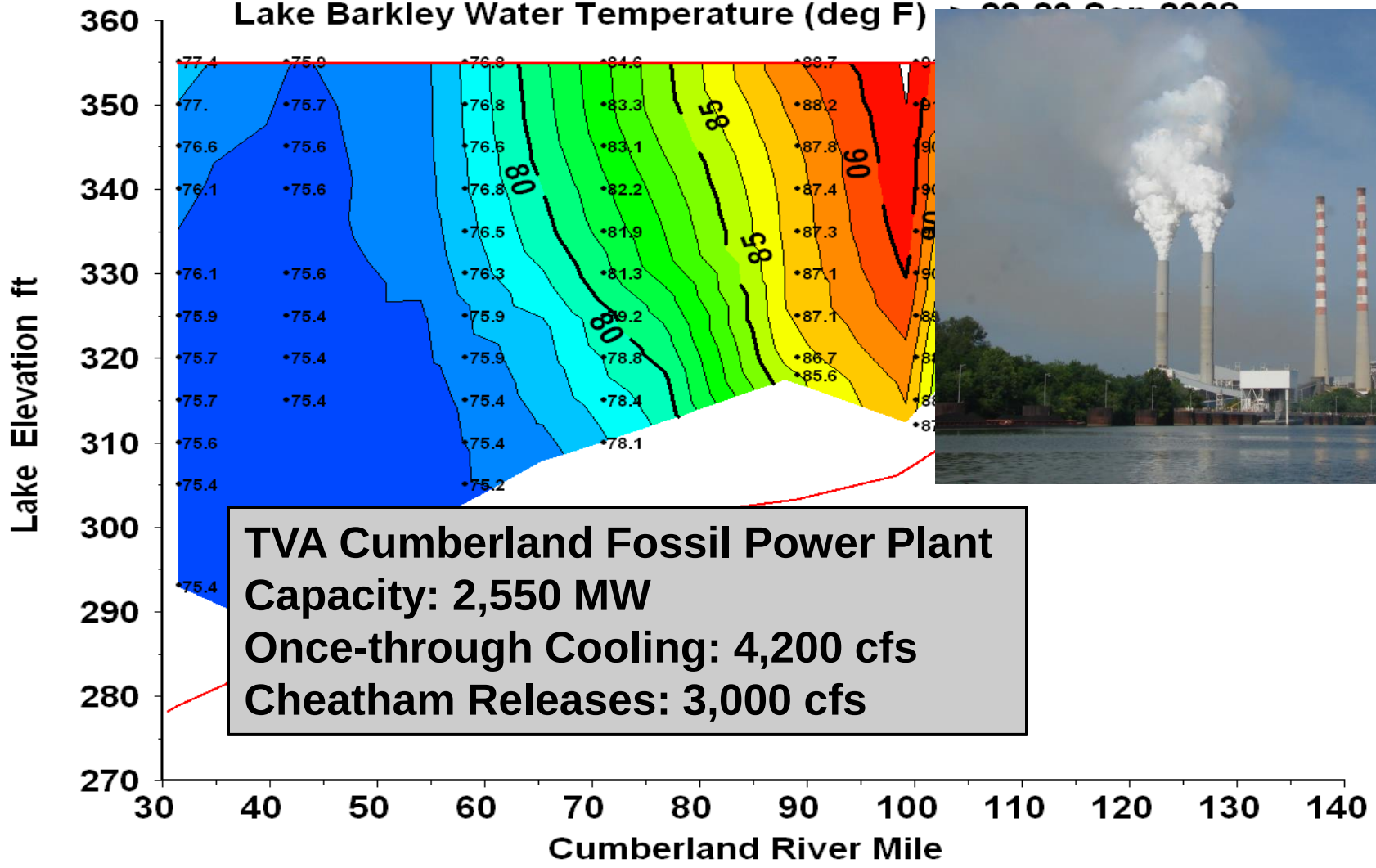


Turbine **Sluice**

Cordell Hull Lake
Dissolved Oxygen Conditions



Barkley – Water Temperature



Environmental Operating Principles

- First published in 2002
  - Seven principles – Corps employees to consider the environment in everything they do
- Reinvigorated EOPs issued in June, 2012
  - More concise
  - Clearer format
  - Increased emphasis on a proactive approach

"The reinvigorated principles provide direction on how the Corps protects and restores natural systems and the environment while encouraging productive, sustainable economic development that improves the quality of life for everyone…" LTG Tom Bostick (08/29/2012)

Environmental Operating Principles (2012 "Reinvigorated" Version)

- **Foster Sustainability** as a way of life throughout the organization.
- **Proactively consider environmental consequences** of all Corps activities and act accordingly.
- Create mutually supporting **economic and environmentally sustainable solutions**.
- Continue to **meet our corporate responsibility and accountability under the law** for activities undertaken by the Corps, which may impact human and natural environments.
- **Consider the environment** in employing a risk management and systems approach throughout life cycles of projects and programs.
- **Leverage scientific, economic and social knowledge** to understand the environmental context and effects of Corps actions in a collaborative manner.
- Employ an **open, transparent process** that respects views of individuals and groups interested in Corps activities.

Water Quality Restoration Physical Modifications

- Wolf Creek
  - Turbine venting on units #1, #3, and #5
    - Hub baffles installed
    - Air supply modified to open in wheel-pit
- Dale Hollow
  - Turbine venting on units #1, #2, and #3
    - Hub baffles installed
    - Supplemental air supply lines installed
- Center Hill
  - Turbine venting on units #1, #2, and #3
    - Hub baffles installed
    - Air supply modified to open in wheel-pit
- J. Percy Priest
  - Fixed-cone valve installed


WOLF CREEK
U5
8 29 01

Dale Hollow Turbine Venting


9 22 '98


92100

Center Hill Turbine Venting

Fixed Cone Valve
J. Percy Priest Dam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Water Quality Restoration Operational Methods

Storage Projects:

- Wolf Creek
  - Orifice and/or sluice gate releases
  - Limits on units in use
- Dale Hollow
  - Sluice gate releases
  - Limits on units in use
- Center Hill
  - Orifice and/or sluice gate releases
  - Limits on units in use
- J. Percy Priest
  - Spillway gate releases
  - Fixed-cone valve releases

Main-stem Projects:

- Cordell Hull
  - Spillway gate releases
- Old Hickory
  - Spillway gate releases
- Cheatham
  - Spillway gate releases
- Barkley
  - Spillway gate releases
  - Shift generation to/from Kentucky
- Manage releases from storage projects

Wolf Creek Turbine & Sluice Releases

Turbine Releases

- Withdraw relatively warm water from mid-depth in lake
- Relatively calm discharge
- Releases can have dissolved oxygen levels < 2 mg/l

Sluice Releases

- Withdraw cold water from deep in the lake
- Turbulent discharge
- Releases are saturated with dissolved oxygen >9 mg/l

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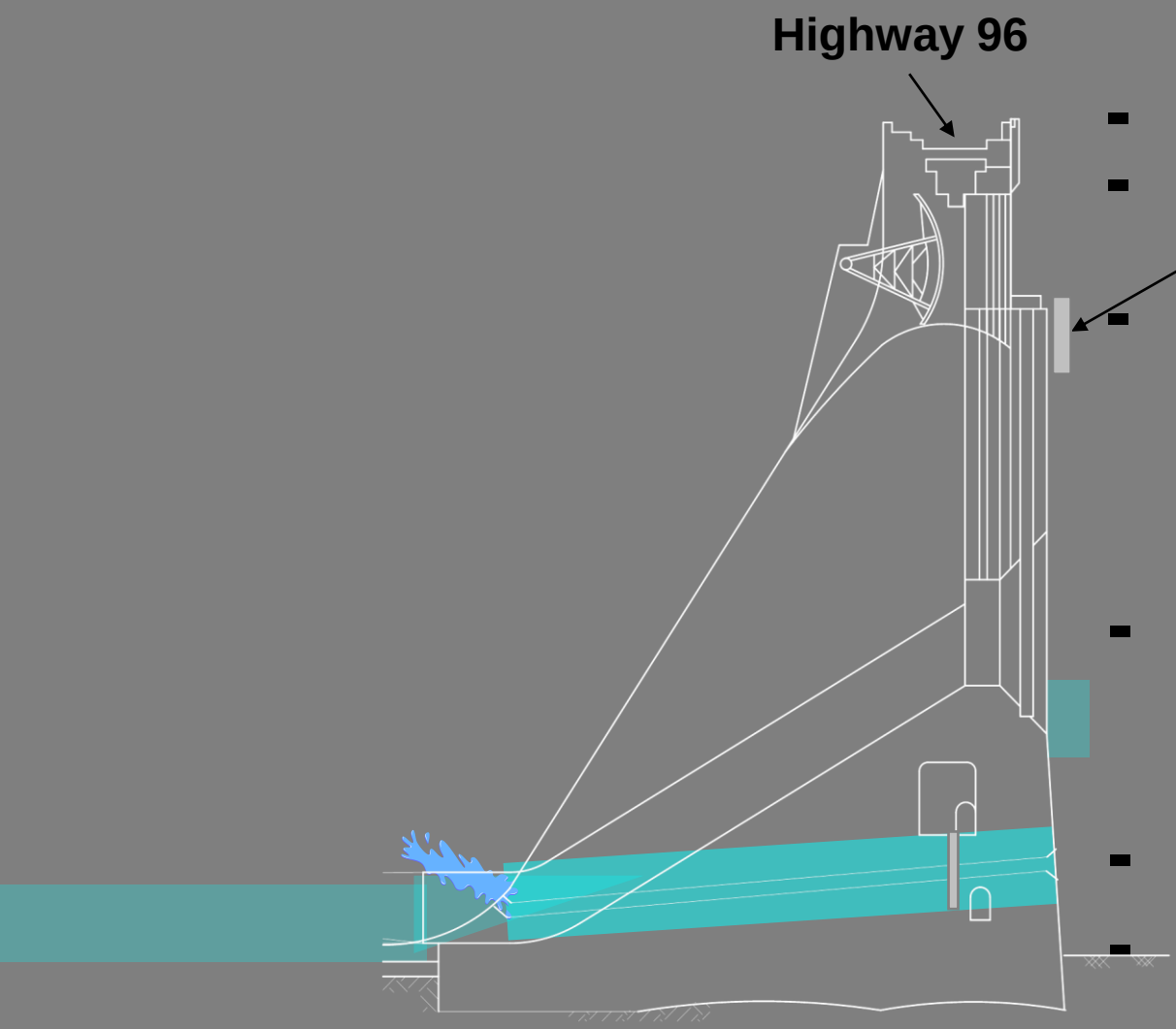
Orifice Gates Wolf Creek & Center Hill

Center Hill Orifice Releases

- Orifice gate release
  - Flow ~ 200 cfs
  - DO ~ 9 mg/l

Center Hill Orifice Gate Installation



- 696 - top of dam
- 685 - flood control pool

orifice gate beginning position

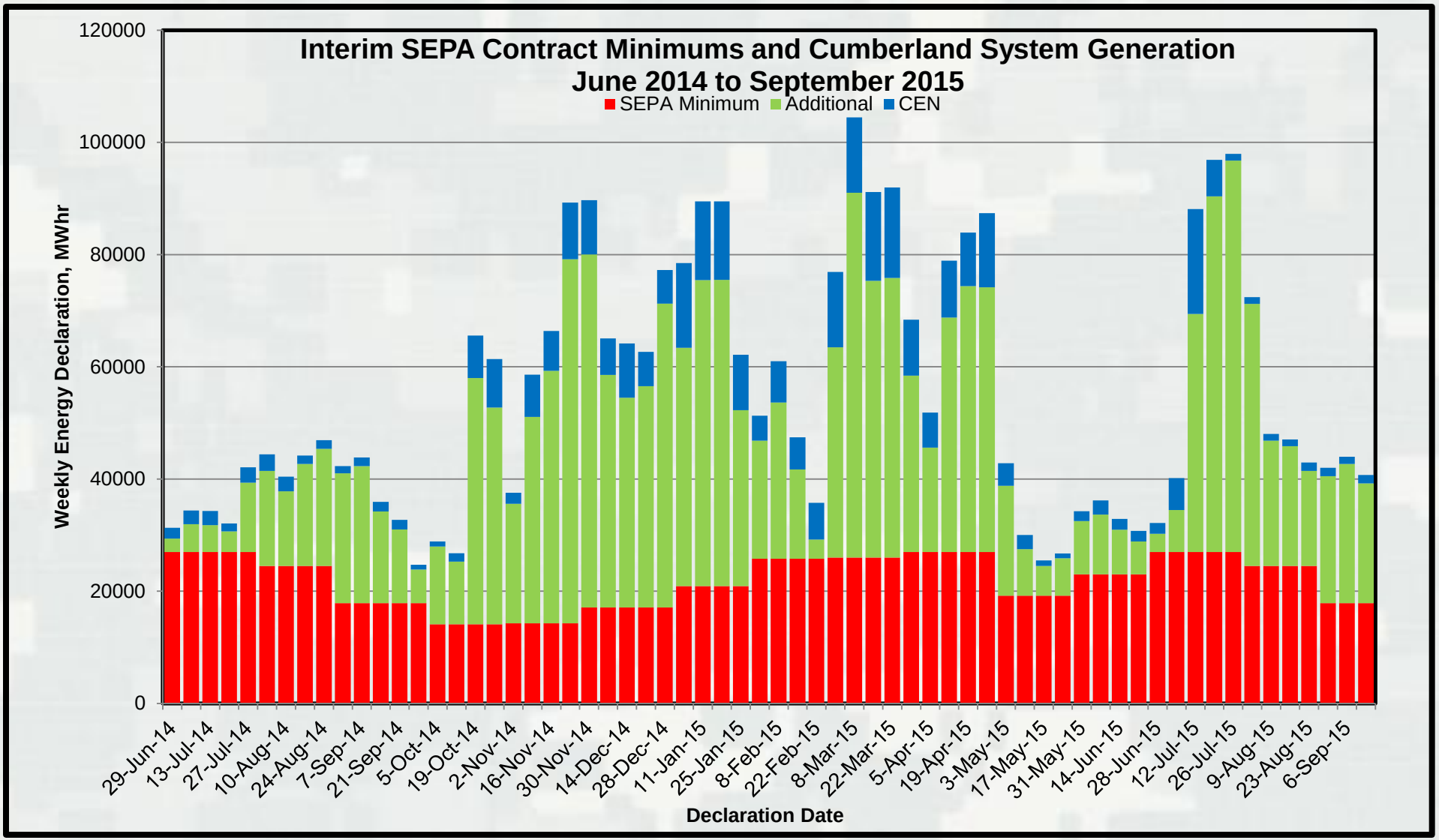
- 648 – top of spillway
- 549.9 – C_L penstock
- 496 – sluice gate
- 470 - streambed

Spillway Releases at Old Hickory Dam

Water Management Criteria for Hydropower and Water Quality

Criteria	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
SEPA Minimum (MWH)	24,000	29,400	32,000	32,000	22,600	24,600	32,200	32,200	21,000	15,800	16,000	20,000
Interim Minimum (MWH)	20,900	25,800	26,000	27,000	19,200	23,000	27,000	24,500	17,900	14,100	14,300	17,100
Flow @ Old Hickory (cfs)	---	---	---	2,000	4,900	7,600	9,100	9,400	7,400	2,000	---	---

Interim Weekly Hydropower Minimums



The Way Ahead

- Update water quality modeling tools
  - Link 2-D water quality models to develop a system water quality model
  - Integrate water quality and hydropower production within a planning level system model to develop seasonal operational schemes
    - Forecast water quality in storage project releases
    - Route storage project flows through main-stem projects
    - Develop operational plan for storage project releases
- Installation of auto-venting turbines at storage projects
  - Significantly reduce (hopefully eliminate) need for sluicing
    - Meeting 6 mg/l at Wolf Creek and Center Hill will be a challenge
    - More difficult when multiple units are in operation
  - Water quality conditions in the Stones River Basin will make meeting DO standard of 5 mg/l standard difficult