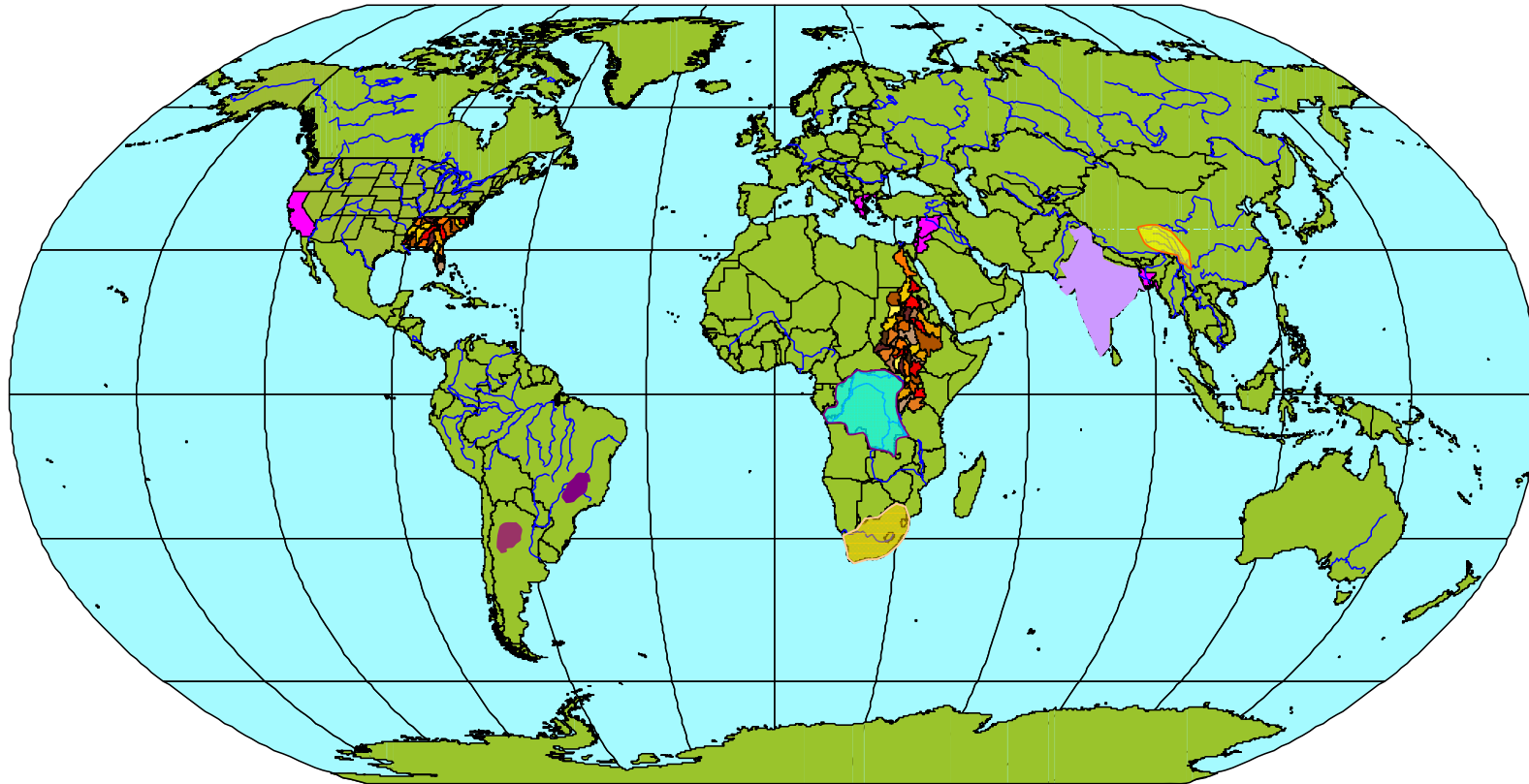


Human history is a race between education and catastrophe.

H. G. Wells

US (Southeast US, California), **South America** (Argentina, Brazil), **Europe** (Greece),
Africa (Nile Basin, Congo, SA), **Middle East** (Jordan, Lebanon), **China** (Yangtze),
India (13 states)



Sponsoring Organizations: USGS, NOAA, NSF, NASA, EPA, CALFED, CEC, COE, Ga EPD, Utilities, Municipalities, Environmental Organizations, FAO/UN, World Bank, USAID, European Aid Agencies (Netherlands, Italy, Sweden, Norway), National Governments

Aris Georgakakos and Huaming Yao
Georgia Water Resources Institute, Georgia Tech
23 July 2010



Flow Requirements (7-Day Average Flow) :

Whitesburg:	1,350 cfs
Columbus:	1,850 cfs
Columbia:	2,000 cfs
Chattahoochee:	IOP

Reservoir Elevation Ranges:

West Point:	621 – 635 ft	(Baseline)
	632.5 – 635 ft	(Scenario 1)
	630 – 635 ft	(Scenario 2)
	635 – 641 ft	(Flood Control)
W.F. George:	187.5 – 190 ft	(Normal)
	185 ft	(Minimum)
J. Woodruff:	76.5 – 77.5 ft	(Normal)

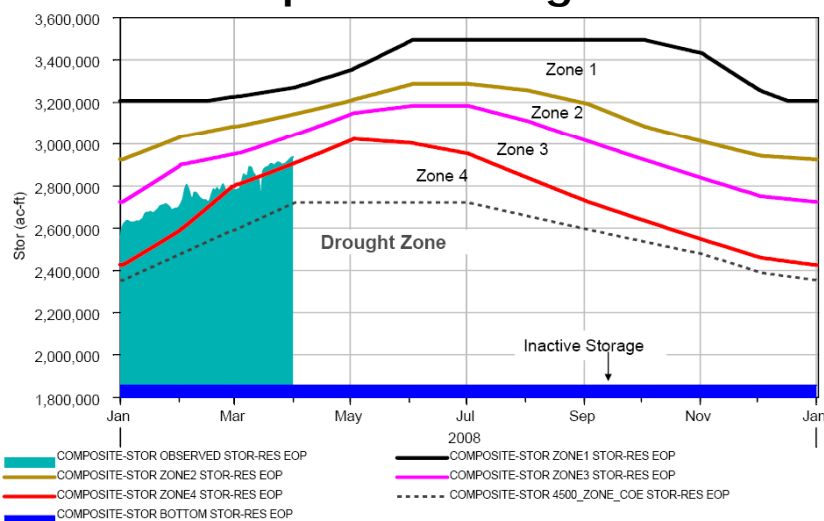
Water Demands:

2007; 2050

- What are the impacts of alternative storage balancing alternatives?
- Can the impacts be addressed through adjustment of the operations plan (IOP)?

Months	Composite Storage Zone	Basin Inflow (BI) (cfs)	Release (cfs)
March -May	Zones 1 and 2	≥ 34000	≥ 25000
		≥ 16000 and < 34000	$\geq 16000 + 50\% * (BI - 16000)$
		≥ 5000 and < 16000	$\geq BI$
	Zone 3	< 5000	≥ 5000
		≥ 39000	≥ 25000
		≥ 11000 and < 39000	$\geq 11000 + 50\% (BI - 11000)$
		≥ 5000 and < 11000	$\geq BI$
June - November	Zones 1,2, and 3	< 5000	≥ 5000
		≥ 24000	≥ 16000
		≥ 8000 and < 24000	$\geq 8000 + 50\% (BI - 8000)$
		≥ 5000 and < 8000	BI
December-February	Zones 1, 2, and 3	< 5000	≥ 5000
		≥ 5000	≥ 5000
All Times	Zone 4	< 5000	≥ 5000
All Times	Drought Zone		≥ 4500

Composite Storage Zones



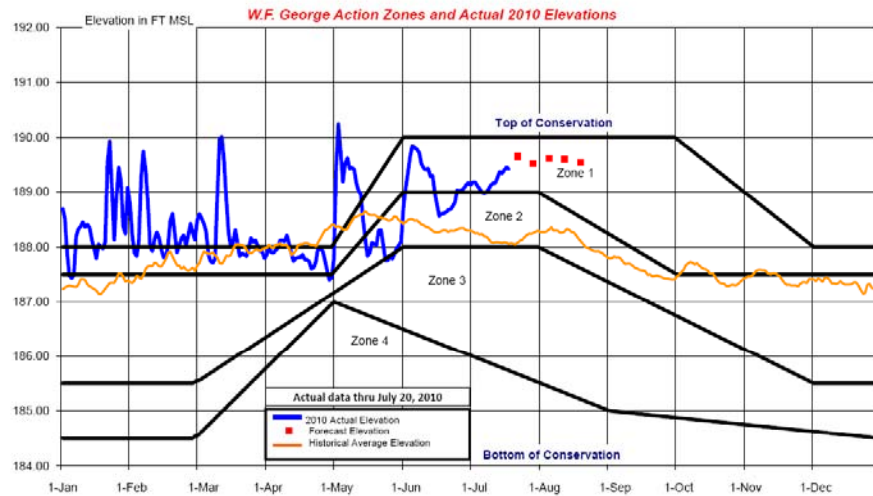
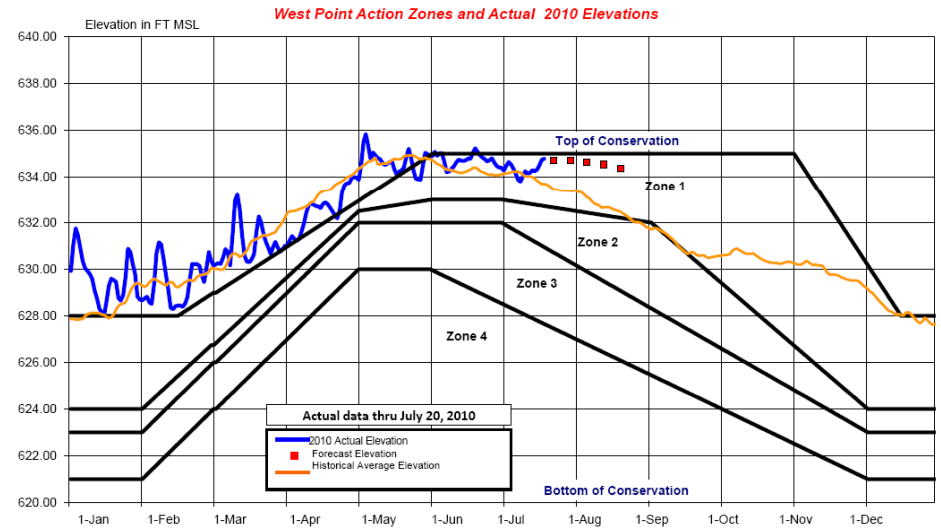
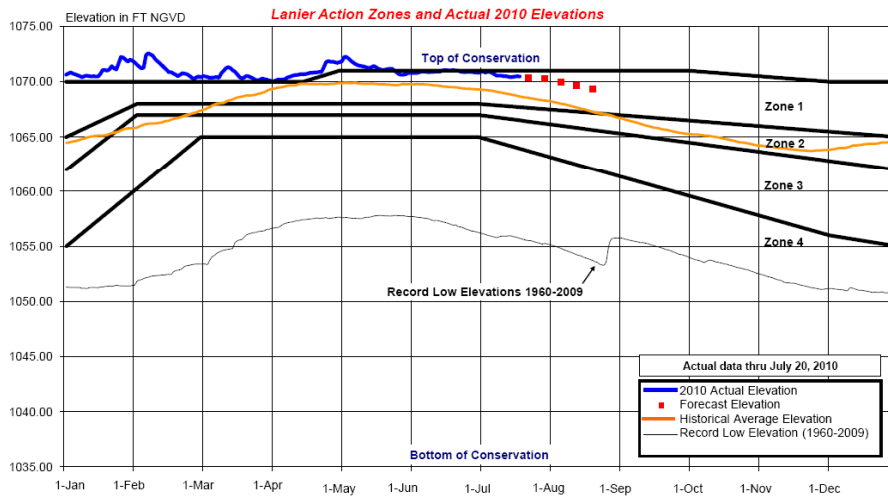
Woodruff Release Limits

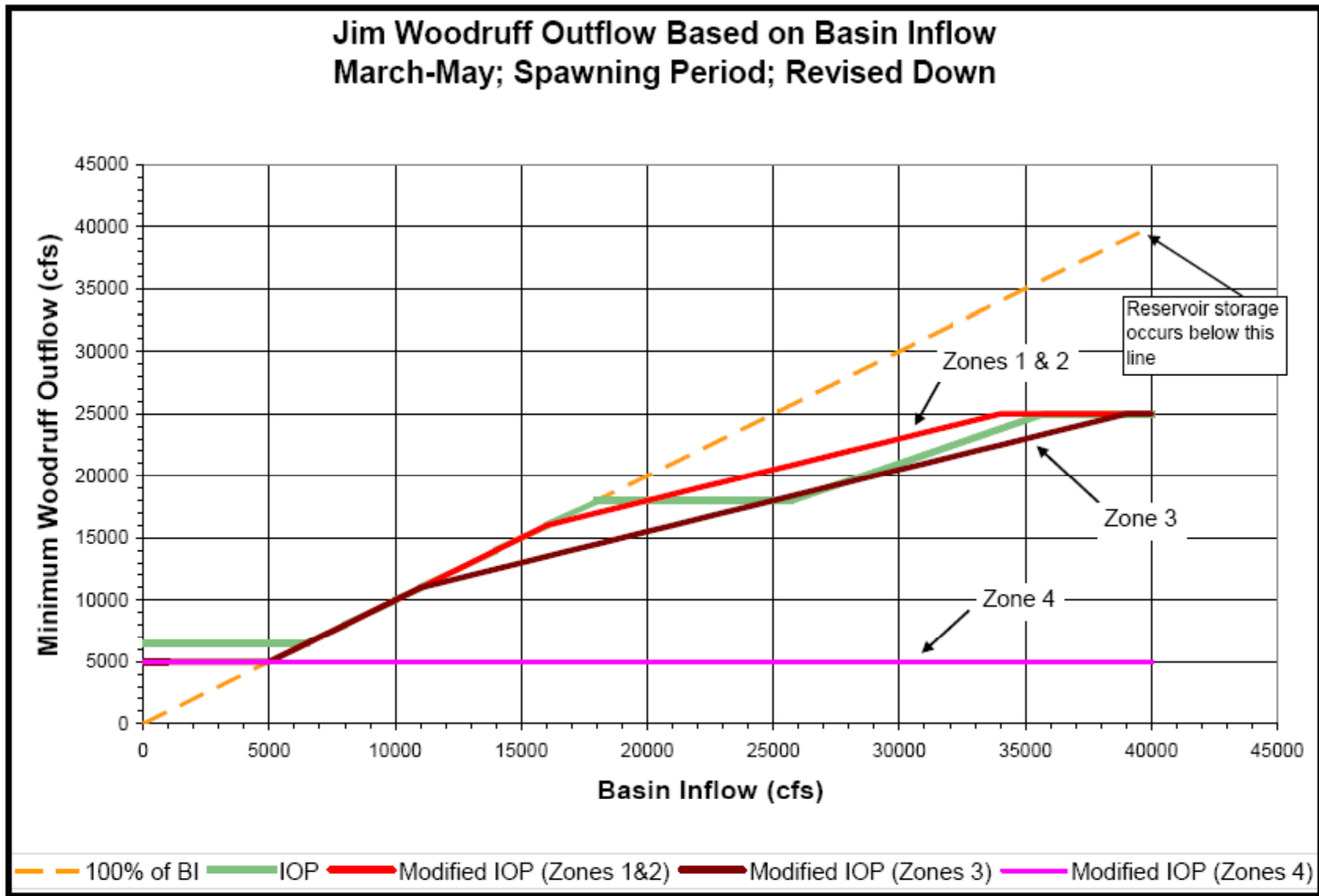
Release Range (cfs)	Max. Fall Rate (ft/day) at Chattahoochee Gage
> 30000	No Restriction
> 20000 and ≤ 30000	1 to 2
> 16000 and ≤ 20000	.5 to 1
> 8000 and < 16000	0.25 to 0.5
< 8000	≤ 0.25

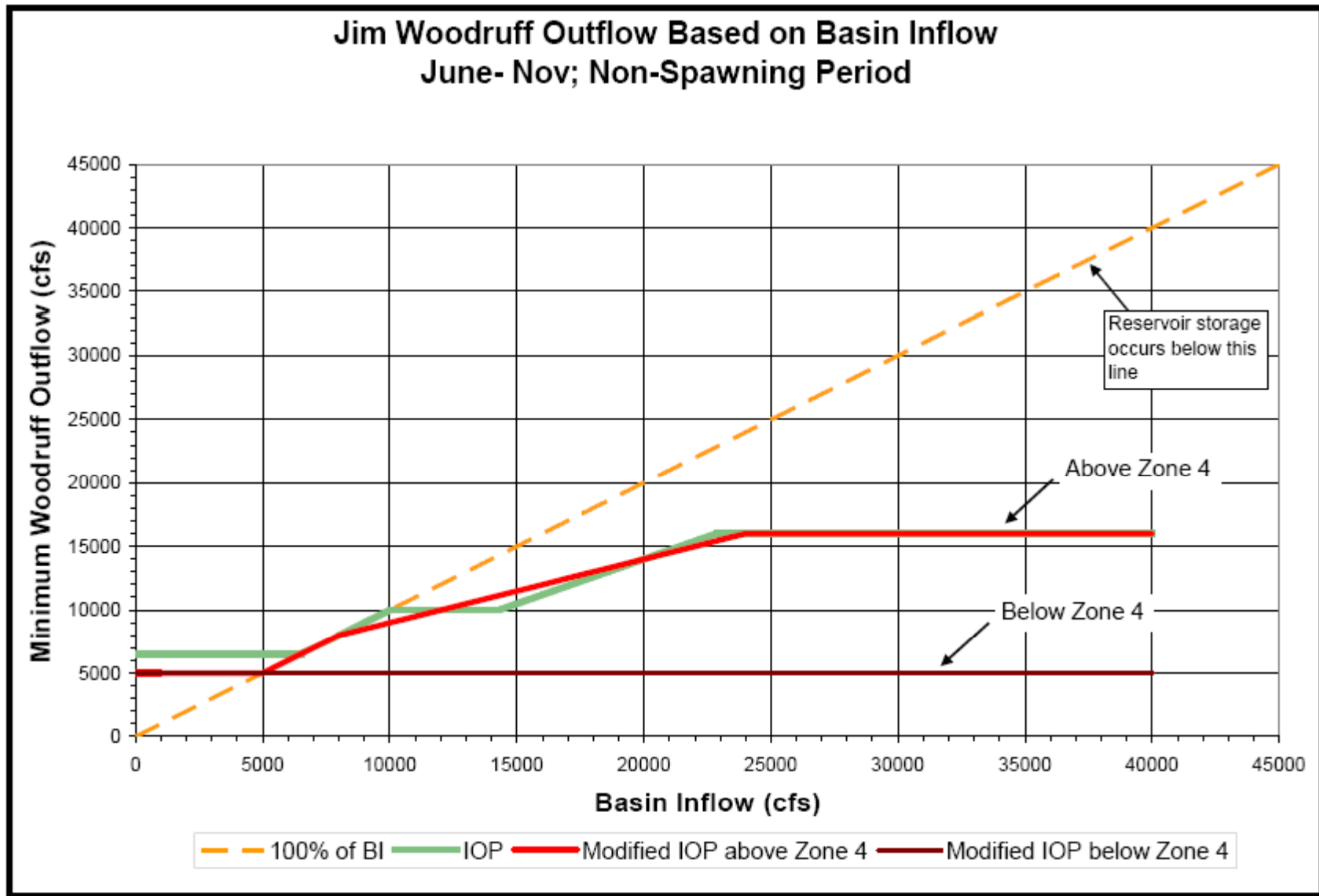
Note: No restrictions in Composite Zone 4.

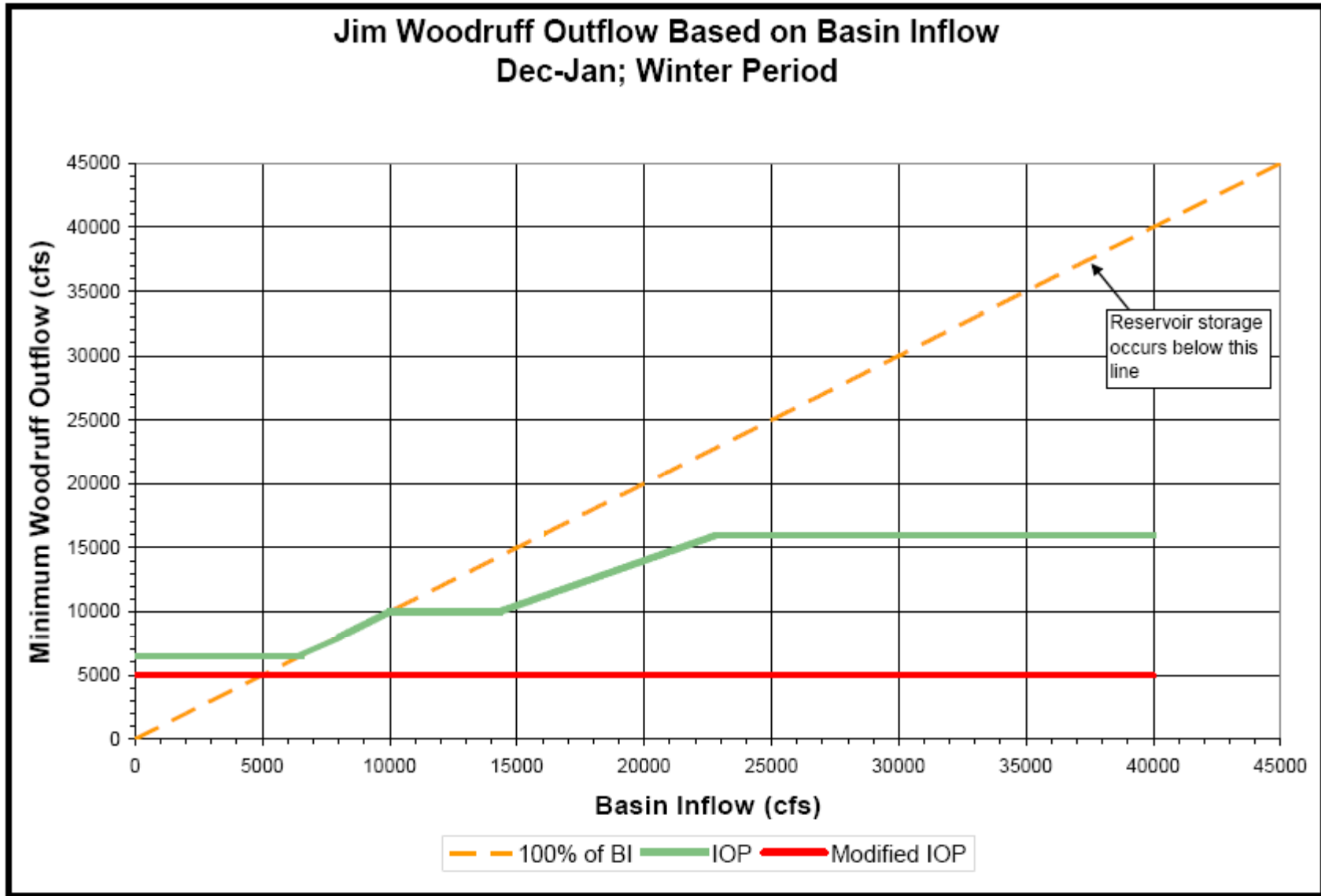
Interim Operations Plan (2)

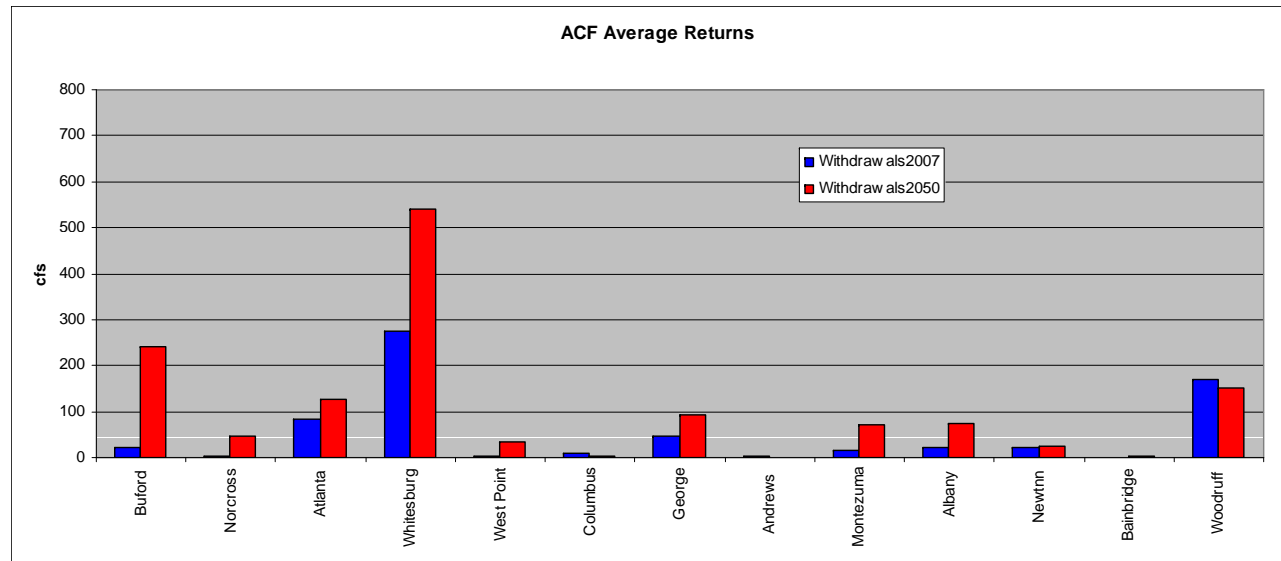
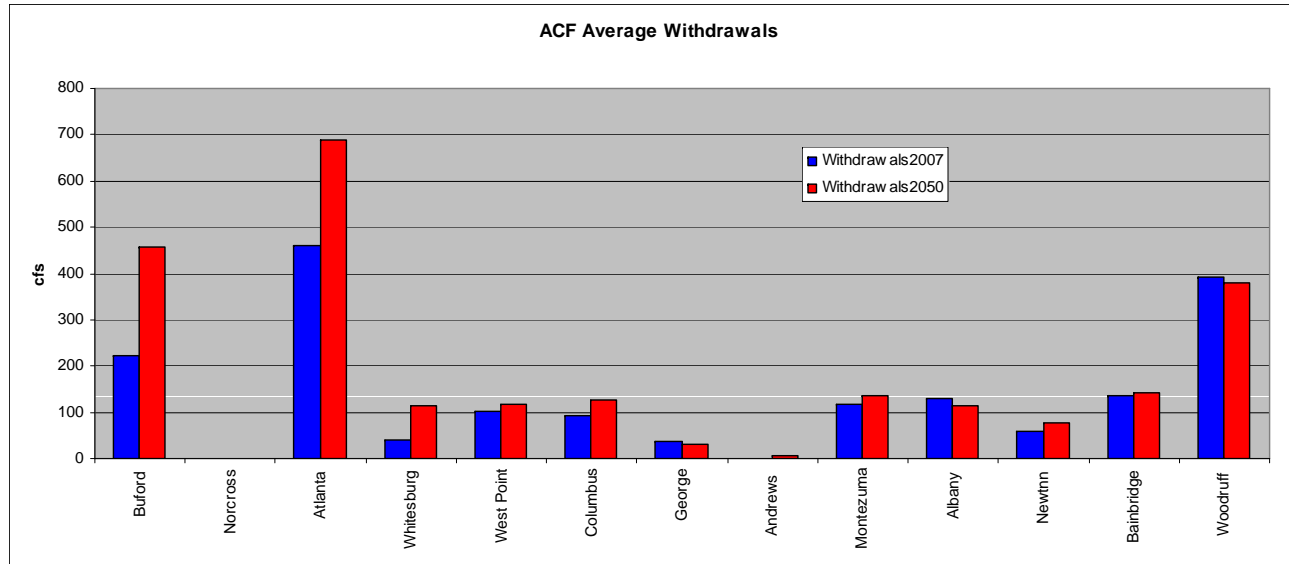
(Reservoir Storage Zones; USACE Website)

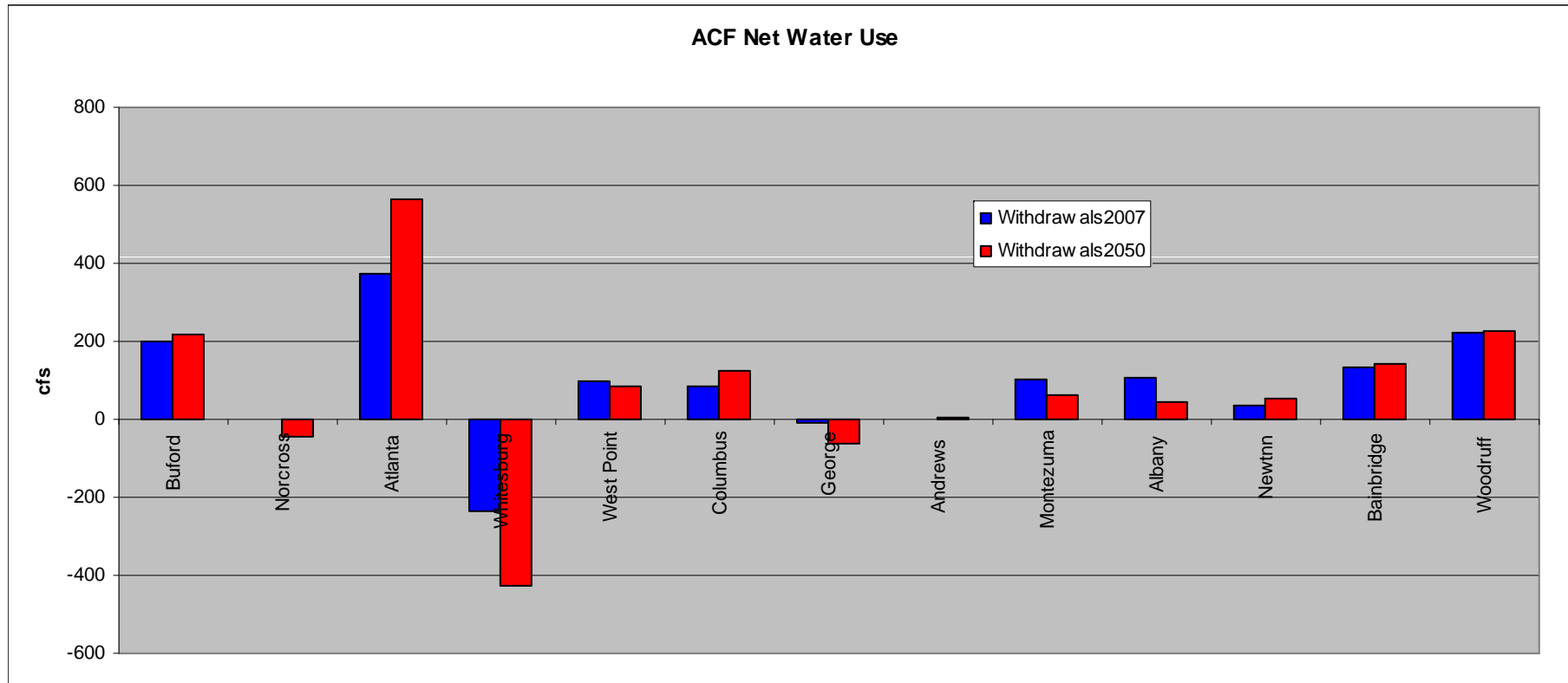




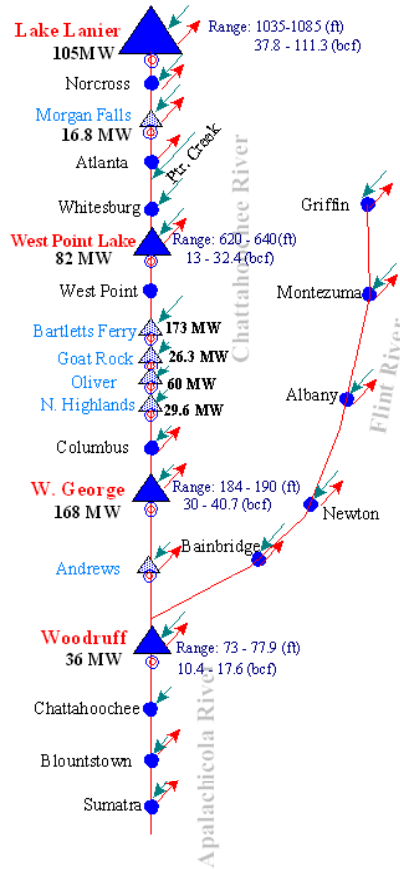
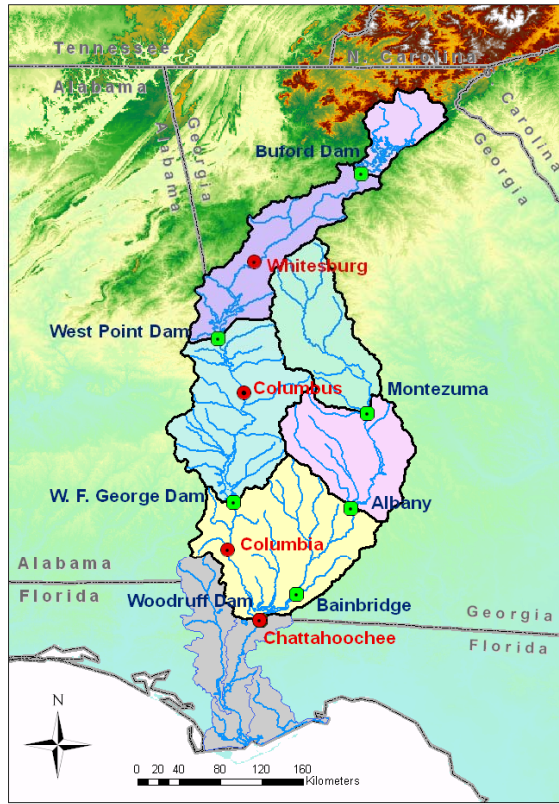






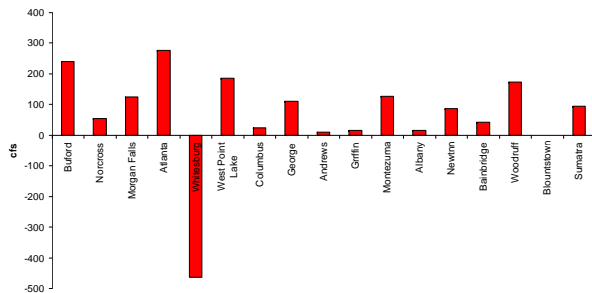
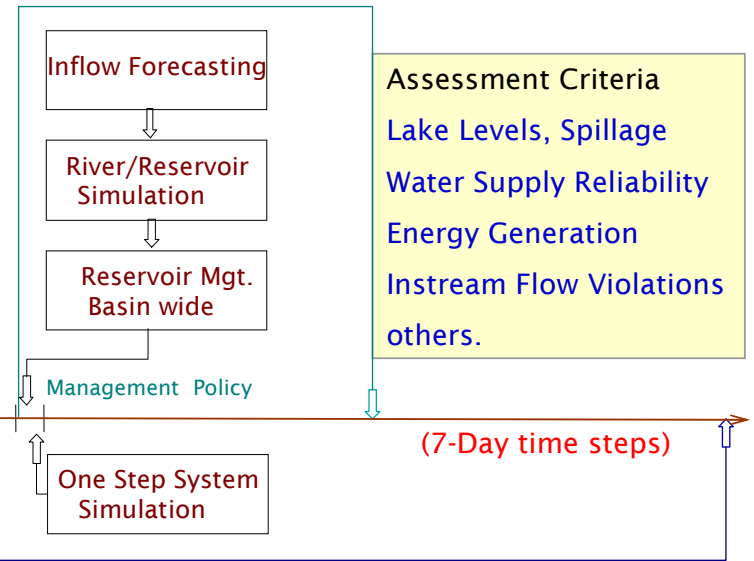


ACF DSS: System Nodes



Adaptive Reservoir Management

6-month Forecast-Decision Horizon



Inflow Scenario
Demand Scenario
Regulation Policy

Simulation Horizon (1939 to 2001)

IOP (Baseline)

Flow Requirements:

(7-Day Average Flow)

Whitesburg: 1,350 cfs
 Columbus: 1,850 cfs
 Columbia: 2,000 cfs
 Chattahoochee: **IOP**

Reservoir Elevation Ranges:

West Point: 621 – 635 ft
 635 – 641 ft
(Flood Control)

W.F. George: 87.5 – 190 ft
(Normal)
 185 ft
(Minimum)

J. Woodruff: 76 – 77.5 ft

Water Demands:

2007; 2050

MCWC-1

Flow Requirements:

(7-Day Average Flow)

Whitesburg: 1,350 cfs
 Columbus: 1,850 cfs
 Columbia: 2,000 cfs
 Chattahoochee: **IOP; MIOP**

Reservoir Elevation Ranges:

West Point: **632.5** – 635 ft
 635 – 641 ft
(Flood Control)

W.F. George: 187.5 – 190 ft
(Normal)
 185 ft
(Minimum)

J. Woodruff: **76.5** – 77.5 ft

Water Demands:

2007; 2050

MCWC-2

Flow Requirements:

(7-Day Average Flow)

Whitesburg: 1,350 cfs
 Columbus: 1,850 cfs
 Columbia: 2,000 cfs
 Chattahoochee: **IOP; MIOP**

Reservoir Elevation Ranges:

West Point: **630** – 635 ft
 635 – 641 ft
(Flood Control)

W.F. George: 187.5 – 190 ft
(Normal)
 185 ft
(Minimum)

J. Woodruff: **76.5** – 77.5 ft

Water Demands:

2007; 2050

IOP (Baseline)

MCWC-1

Flow Requirements *(7-Day Average Flow):*

Whitesburg:	1,350 cfs
Columbus:	1,850 cfs
Columbia:	2,000 cfs
Chattahoochee:	IOP

Reservoir Elevation Ranges:

West Point:	621 - 635 ft
	635 - 641 ft <i>(Fld. Cntrl.)</i>

W.F. George:	187.5 - 190 ft <i>(Normal)</i>
	185 ft <i>(Minimum)</i>

J. Woodruff:	76 - 77.5 ft
--------------	--------------

Water Demands:

2007

Flow Requirements *(7-Day Average Flow):*

Whitesburg:	1,350 cfs
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West Point:	632.5 - 635 ft
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W.F. George:	187.5 - 190 ft <i>(Normal)</i>
	185 ft <i>(Minimum)</i>

J. Woodruff:	76.5 - 77.5 ft
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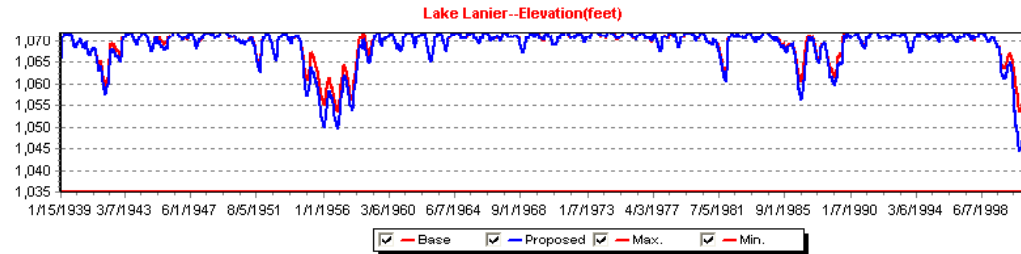
Water Demands:

2007

Assessment Results

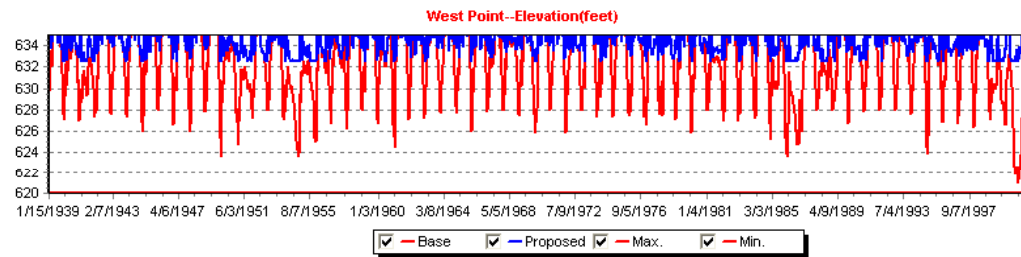
Reservoir Levels (2007 Demands; IOP; MCWC-1)

Lanier

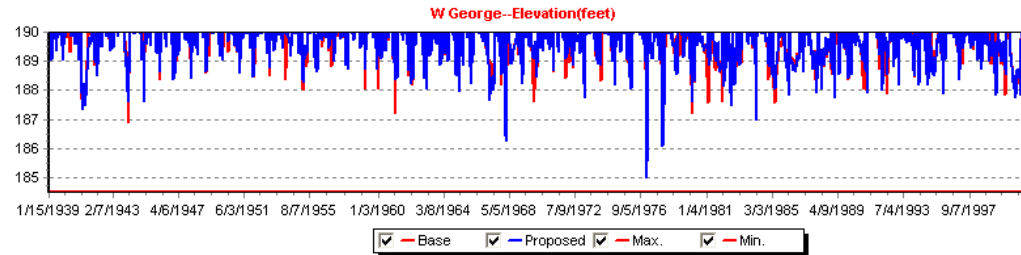


→ Baseline
→ MCWC Scenario 1

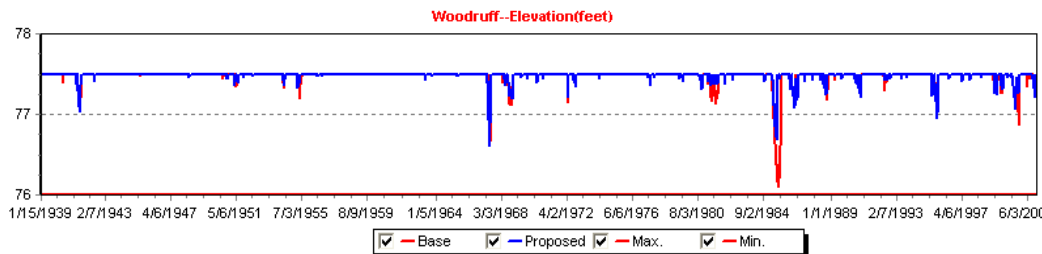
W. Point



George



Woodruff

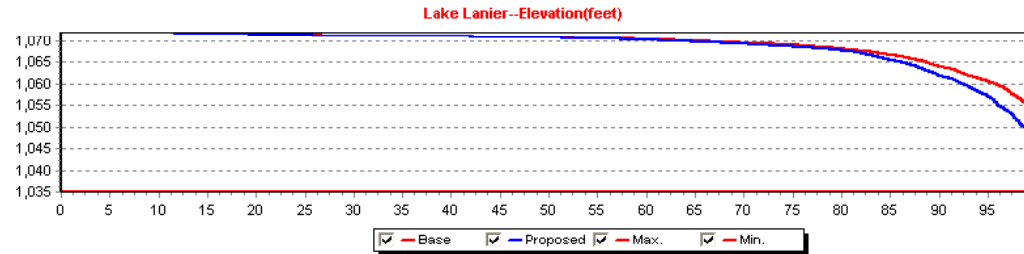


- Lanier impact: Deeper drawdowns during severe droughts (~5-9 ft, 4%).
- West Point benefit: Levels stay above 632.5 at all time.

Assessment Results

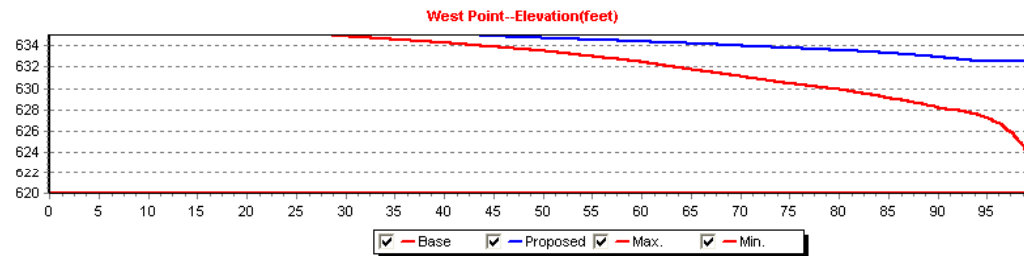
Reservoir Levels (2007 Demands; IOP; MCWC-1)

Lanier

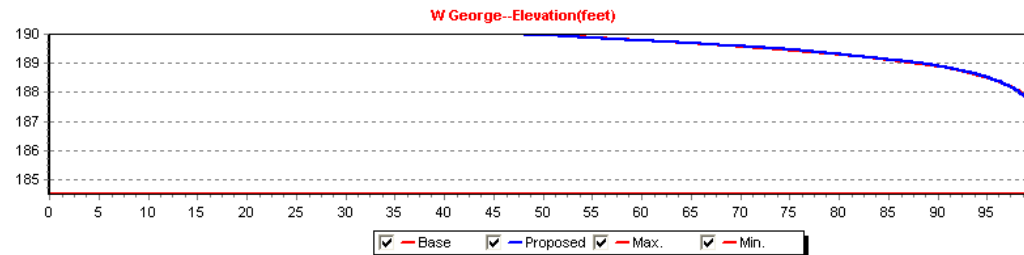


→ Baseline
→ MCWC Scenario 1

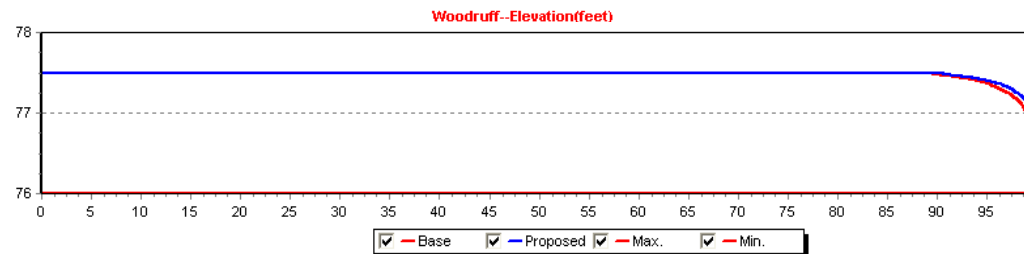
W. Point



George



Woodruff



- Lanier impact: Deeper drawdowns during severe droughts (~5-9 ft, 4%).
- West Point benefit: Levels stay above 632.5 at all time.

- Lanier impact: Deeper drawdowns during severe droughts (~5-9 ft, 4%).
- West Point benefit: Levels stay above 632.5 at all time.
- Instream flow targets are always met—no significant violations.
- Energy generation increases (~4%) at West Point under MCWC Scenario 1.
- Water demand targets are met at all locations under both the **Baseline** and the **MCWC Scenario 1**.

IOP (Baseline)

Flow Requirements:

Chattahoochee: **IOP**

Reservoir Elevation Ranges:

West Point: **621 - 635 ft**
 635 - 641 ft (*Fld. Cntrl.*)
 W.F. George: 187.5 - 190 ft (*Normal*)
 185 ft (*Minimum*)
 J. Woodruff: **76 - 77.5 ft**

Water Demands:

2007

MCWC-1

Flow Requirements:

Chattahoochee: **IOP**

Reservoir Elevation Ranges:

West Point: **632.5 - 635 ft**
 635 - 641 ft (*Fld. Cntrl.*)
 W.F. George: 187.5 - 190 ft (*Normal*)
 185 ft (*Minimum*)
 J. Woodruff: **76.5 - 77.5 ft**

Water Demands:

2007

MCWC-2

Flow Requirements:

Chattahoochee: **IOP**

Reservoir Elevation Ranges:

West Point: **630 - 635 ft**
 635 - 641 ft (*Fld. Cntrl.*)
 W.F. George: 187.5 - 190 ft (*Normal*)
 185 ft (*Minimum*)
 J. Woodruff: **76.5 - 77.5 ft**

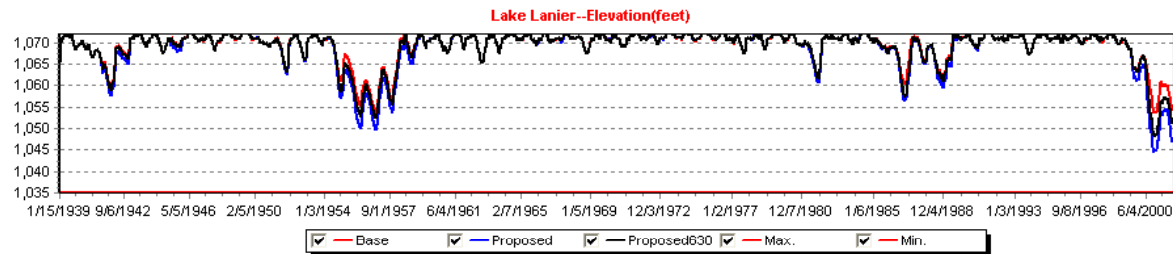
Water Demands:

2007

Reservoir Levels

(2007 Demands; IOP; MCWC-1; MCWC-2)

Lanier

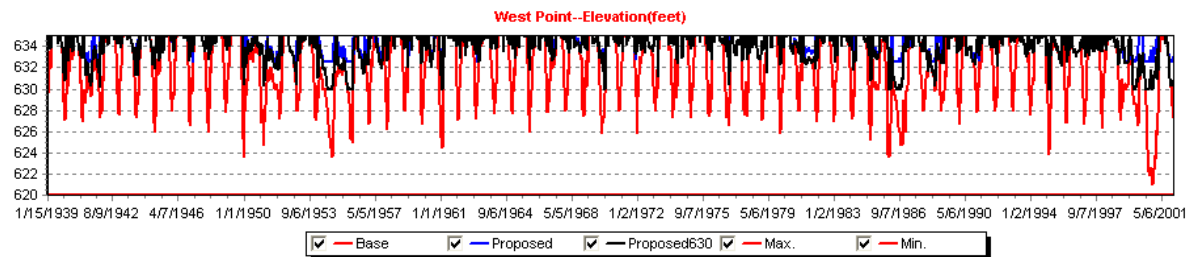


Baseline

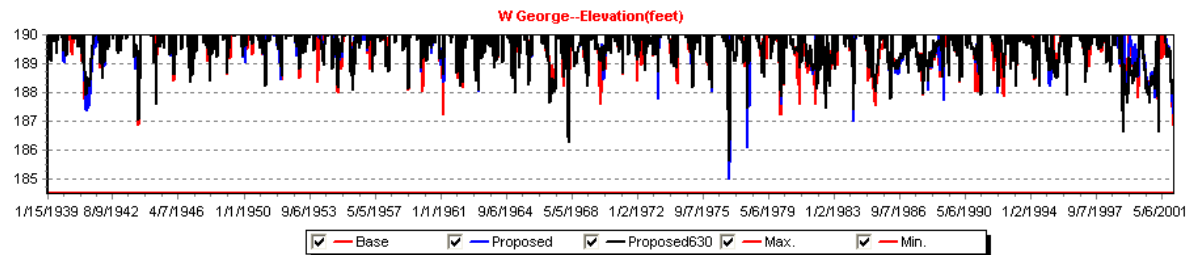
MCWC-2

MCWC-1

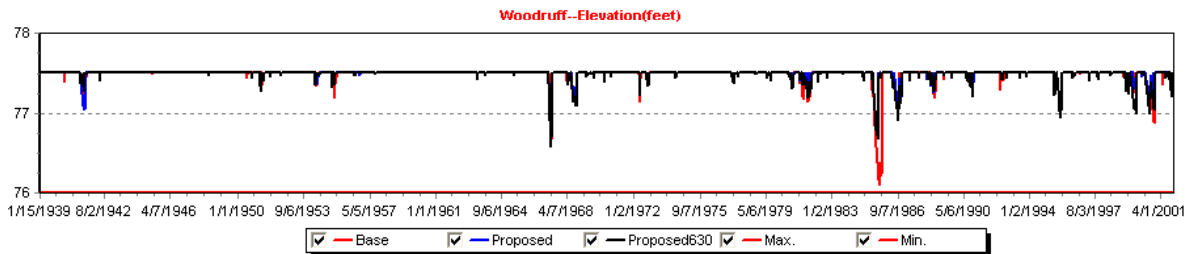
W. Point



George



Woodruff

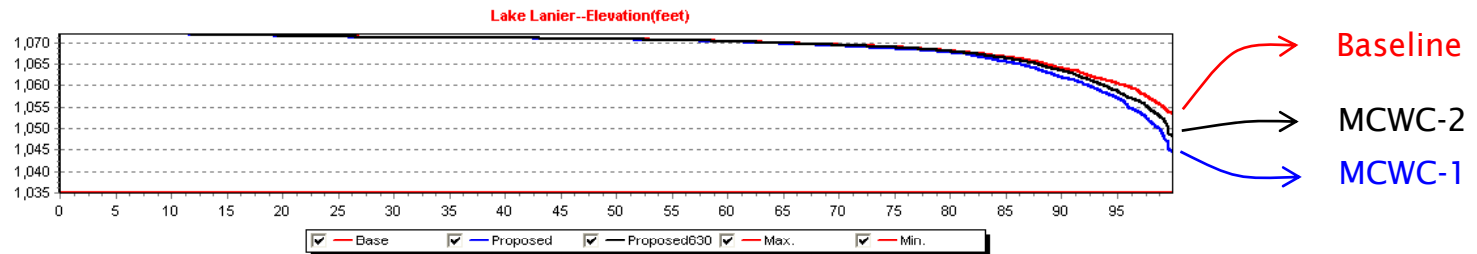


- Lanier impact: (MCWC-1 or MCWC-2) vs. Baseline: ~5-9 ft deeper drawdowns.
- West Point: Levels stay above 630 or 632.5 ft at all times.

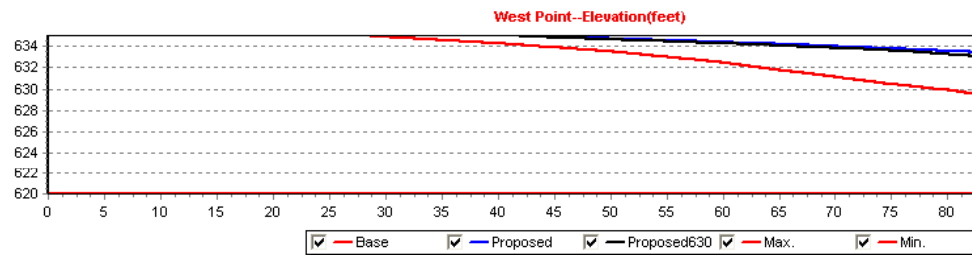
Reservoir Levels

(2007 Demands; **IOP**; **MCWC-1**; MCWC-2)

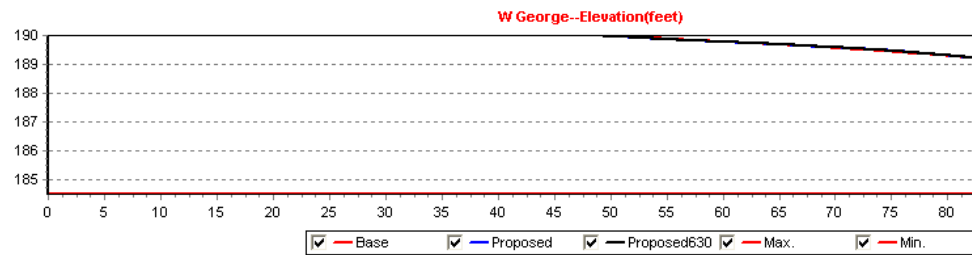
Lanier



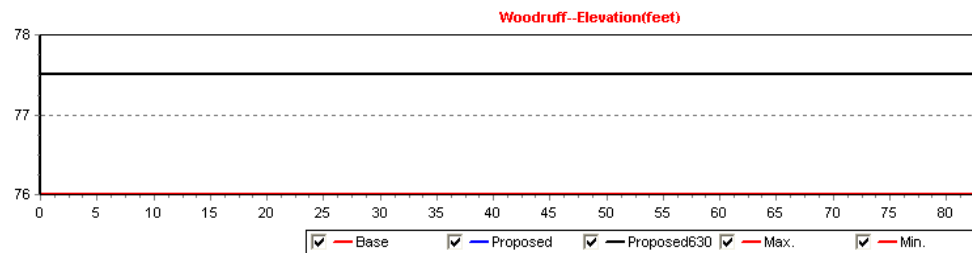
W. Point



George



Woodruff



- **Lanier impact:** (MCWC-1 or MCWC-2) vs. **Baseline:** ~5-9 ft deeper drawdowns.
- **West Point:** Levels stay above 630 or **632.5** ft at all times.

IOP/2007

Flow Requirements:

Chattahoochee: **IOP**

Reservoir Elevation Ranges:

West Point: **621 - 635 ft**
 635 - 641 ft (*Fld. Cntrl.*)
 W.F. George: 187.5 - 190 ft (*Normal*)
 185 ft (*Minimum*)
 J. Woodruff: **76 - 77.5 ft**

Water Demands:

2007

MCWC-1/2050

Flow Requirements:

Chattahoochee: **IOP**

Reservoir Elevation Ranges

West Point: **632.5 - 635 ft**
 635 - 641 ft (*Fld. Cntrl.*)
 W.F. George: 187.5 - 190 ft (*Normal*)
 185 ft (*Minimum*)
 J. Woodruff: **76.5 - 77.5 ft**

Water Demands:

2050

MCWC-2/2050

Flow Requirements:

Chattahoochee: **IOP**

Reservoir Elevation Ranges

West Point: **630 - 635 ft**
 635 - 641 ft (*Fld. Cntrl.*)
 W.F. George: 187.5 - 190 ft (*Normal*)
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 J. Woodruff: **76.5 - 77.5 ft**

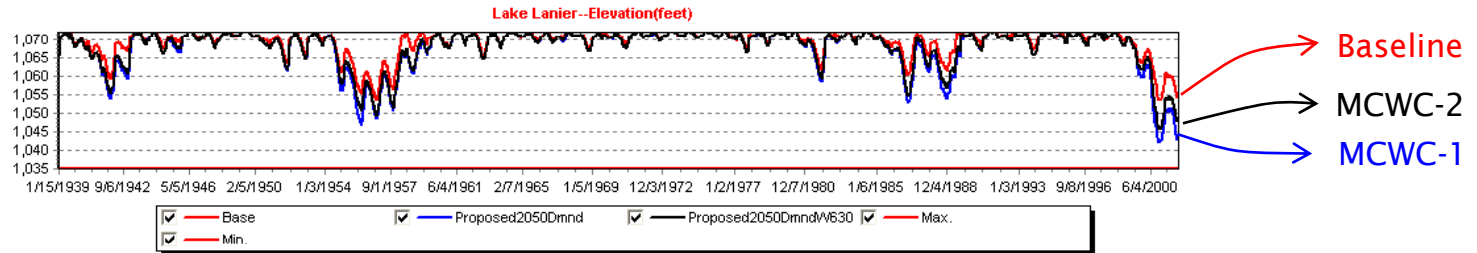
Water Demands:

2050

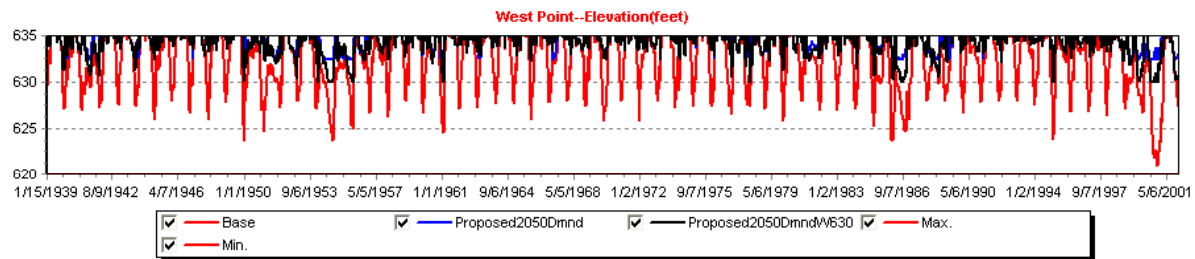
Reservoir Levels

(Baseline/2007; MCWC-1/2050; MCWC-2/2050)

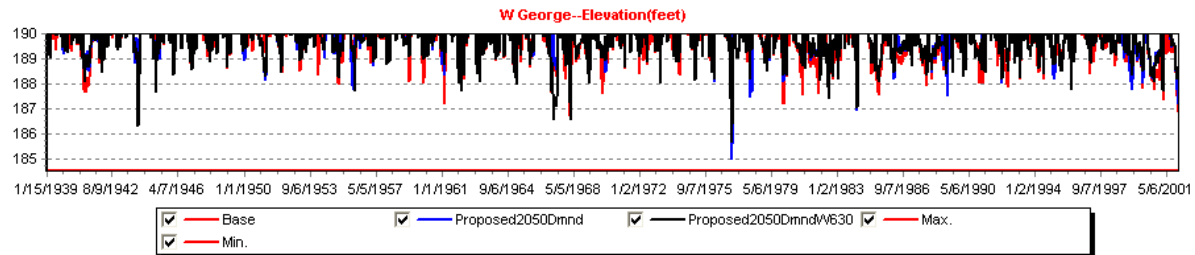
Lanier



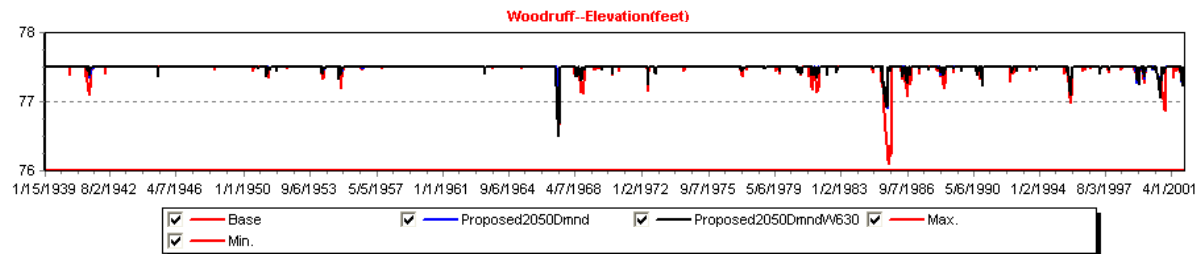
W. Point



George



Woodruff

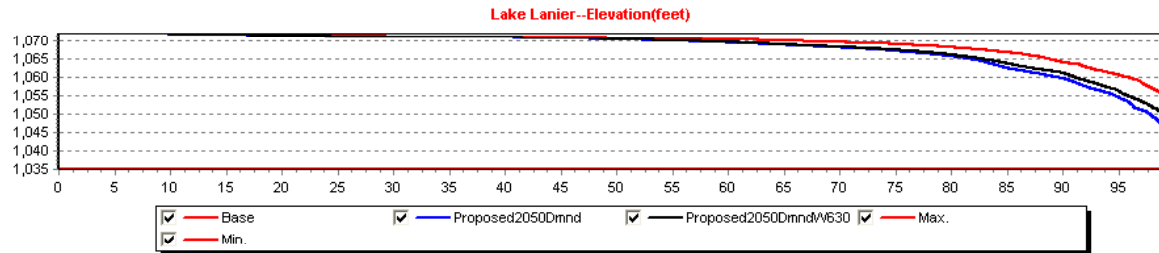


- Lanier: (MCWC-1 or MCWC-2) vs. Baseline: ~9-11 ft deeper drawdowns.
- West Point: Levels stay above 630 or 632.5 ft at all times.

Reservoir Levels

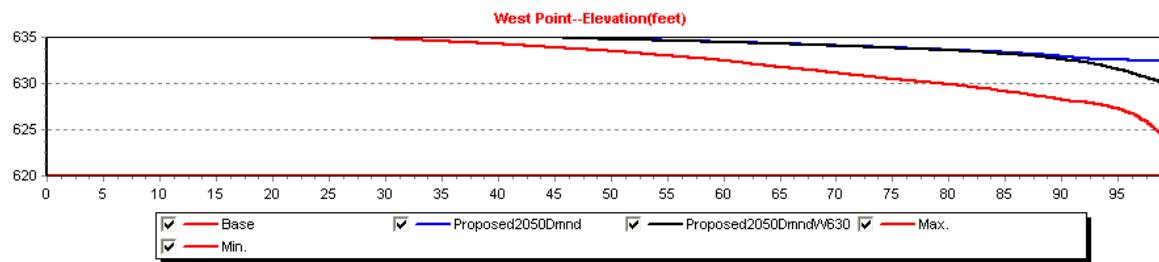
(Baseline/2007; MCWC-1/2050; MCWC-2/2050)

Lanier

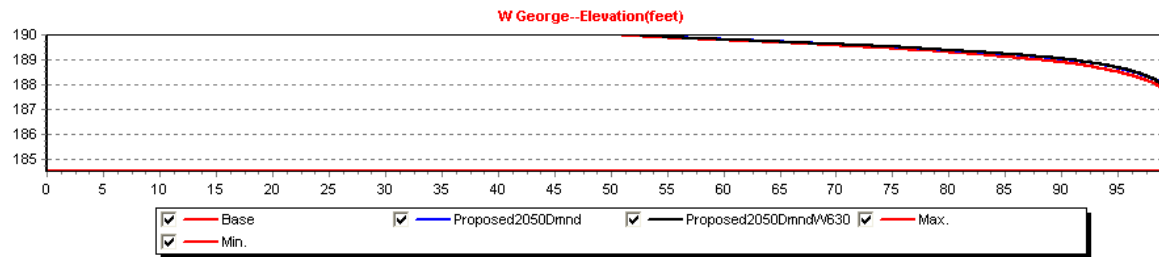


→ Baseline
→ MCWC-2
→ MCWC-1

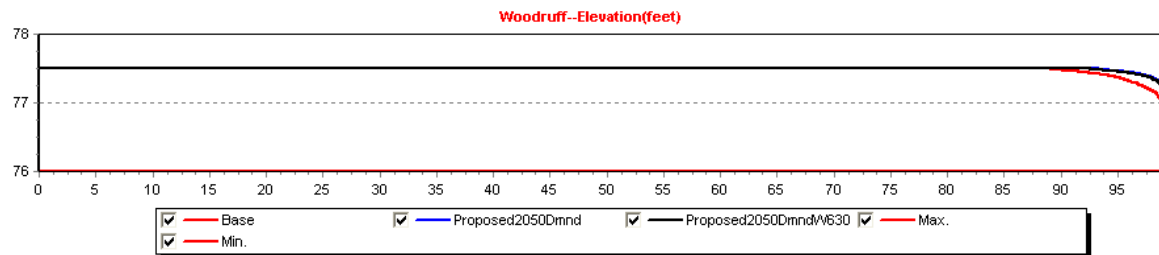
W. Point



George



Woodruff



- Lanier: (MCWC-1 or MCWC-2) vs. Baseline: ~9-11 ft deeper drawdowns.
- West Point: Levels stay above 630 or 632.5 ft at all times.

Modified IOP (MIOP):

Q_{min} : Minimum Flow at Chattahoochee gage, FL

W : ACF inflows above Chattahoochee

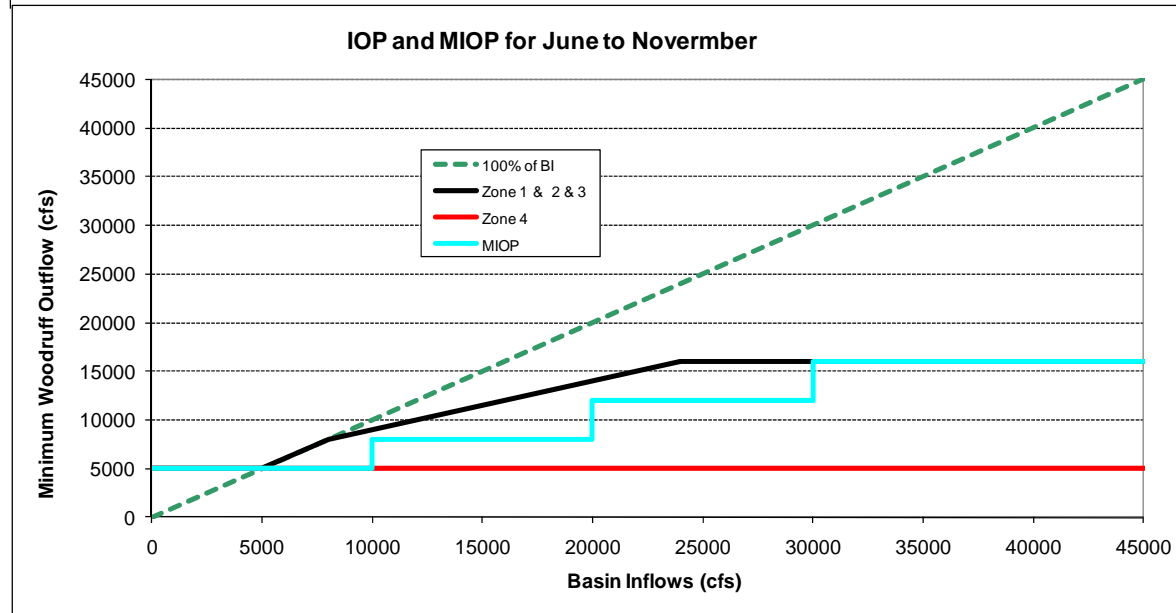
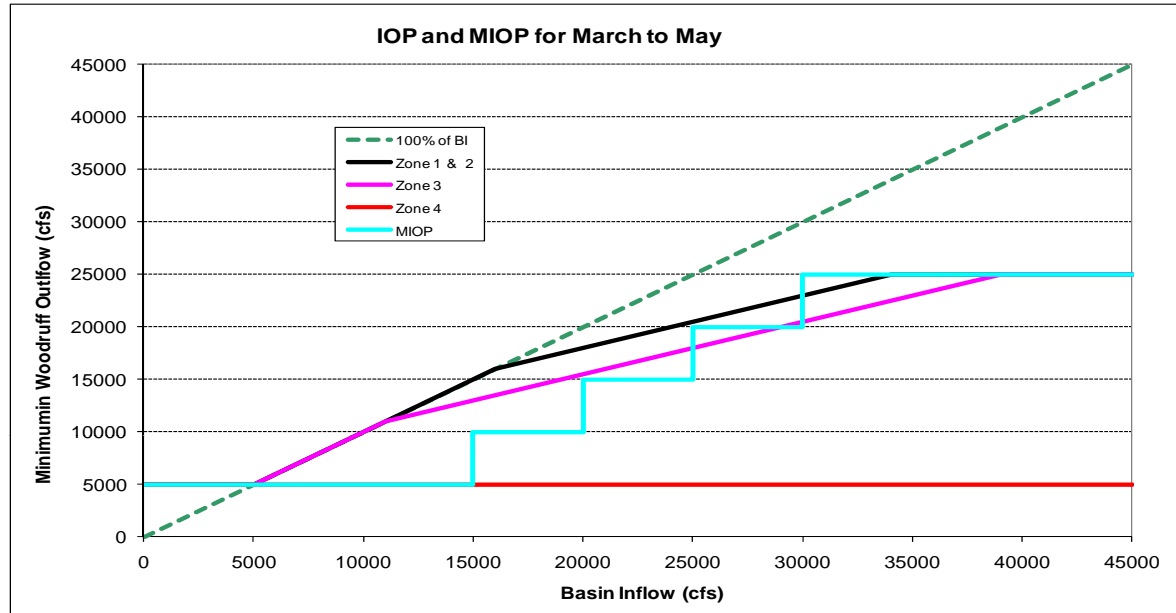
March to May:

$Q_{min} =$	25,000 cfs,	if $W \geq 30,000$ cfs
	20,000 cfs,	if $25,000 \leq W < 30,000$ cfs
	15,000 cfs	if $20,000 \leq W < 25,000$ cfs
	10,000 cfs	if $15,000 \leq W < 20,000$ cfs
	5,000 cfs,	otherwise.

Rest of the Year:

$Q_{min} =$	16,000 cfs,	if $W \geq 30,000$ cfs
	12,000 cfs,	if $20,000 \leq W < 30,000$ cfs
	8,000 cfs,	if $10,000 \leq W < 20,000$ cfs
	5,000 cfs,	otherwise.

Note: The MIOP is based on the original IOP but is modified to enable the reservoirs to recover faster after a severe drought.



IOP (Baseline)

MIOP

Flow Requirements *(7-Day Average Flow):*

Whitesburg:	1,350 cfs
Columbus:	1,850 cfs
Columbia:	2,000 cfs
Chattahoochee:	IOP

Reservoir Elevation Ranges:

West Point:	621 – 635 ft
	635 – 641 ft <i>(Fld. Cntrl.)</i>

W.F. George:	187.5 – 190 ft <i>(Normal)</i>
	185 ft <i>(Minimum)</i>

J. Woodruff:	76 – 77.5 ft
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Water Demands:

2007

Flow Requirements *(7-Day Average Flow):*

Whitesburg:	1,350 cfs
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Columbia:	2,000 cfs
Chattahoochee:	MIOP

Reservoir Elevation Ranges:

West Point:	621 – 635 ft
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	185 ft <i>(Minimum)</i>

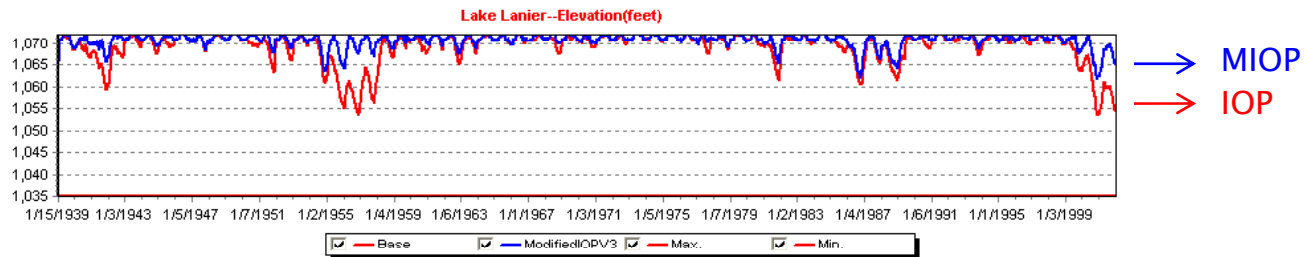
J. Woodruff:	76 – 77.5 ft
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Water Demands:

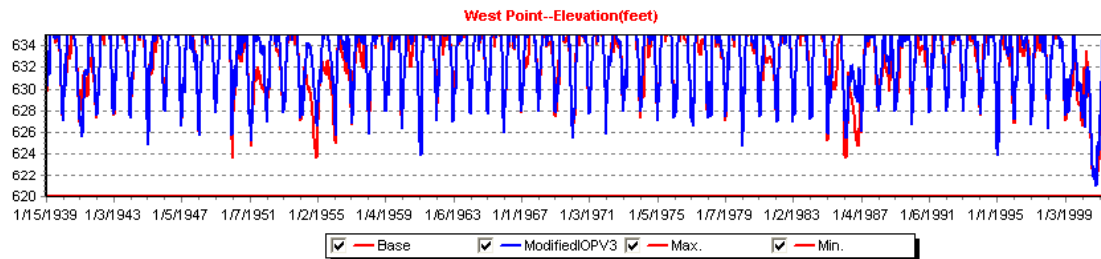
2007

Modified IOP Assessments (2007 Demands; IOP; MIOP)

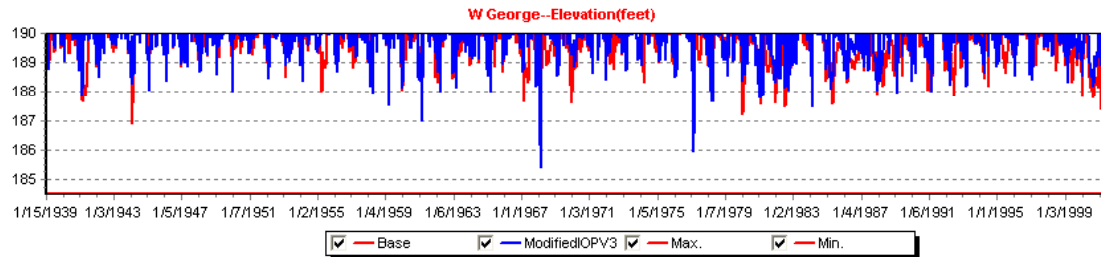
Lanier



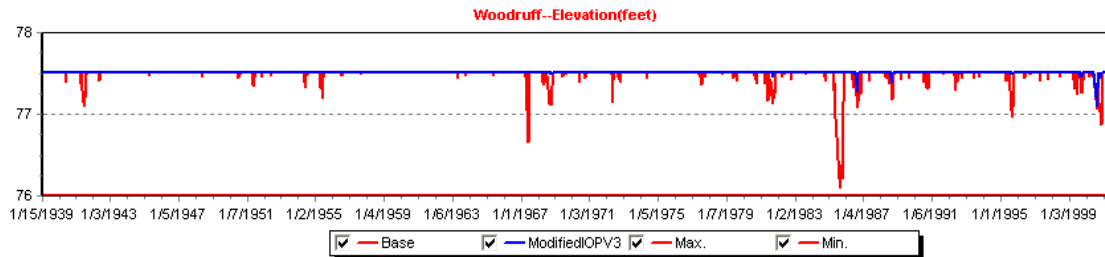
W. Point



George

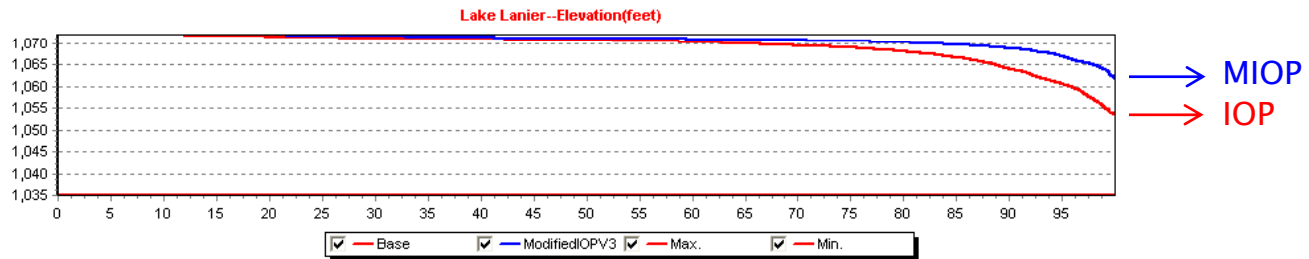


Woodruff

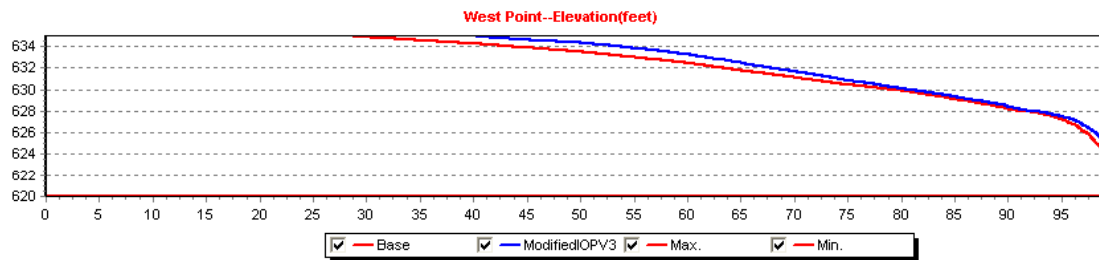


- Lanier: Up to 10 ft deeper drawdowns under IOP than under MIOP.
- West Point: 1-2 ft deeper drawdowns under IOP than under MIOP.

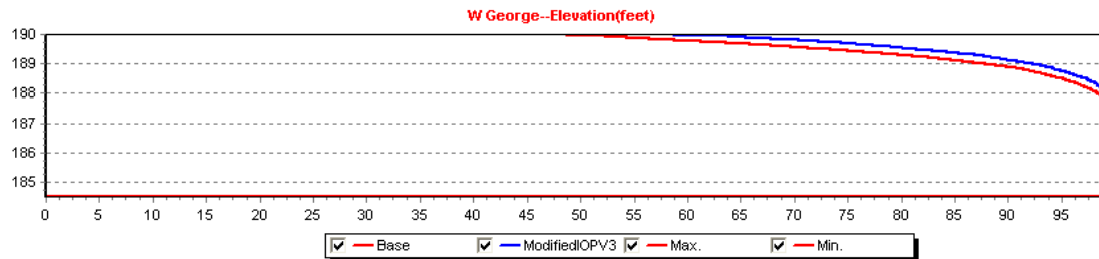
Lanier



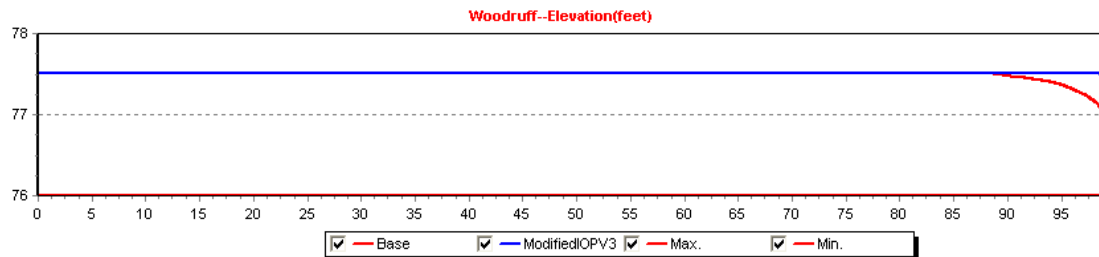
W. Point



George



Woodruff



- Lanier: Up to 10 ft deeper drawdowns under IOP than under MIOP.
- West Point: 1-2 ft deeper drawdowns under IOP than under MIOP.

IOP/2050

Flow Requirements:

Chattahoochee: **IOP**

Reservoir Elevation Ranges:

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Water Demands:

2050

MCWC-1/2050

MCWC-2/2050

Flow Requirements:

Chattahoochee: **MIOP**

Reservoir Elevation Ranges

West Point: **632.5 - 635 ft**
 635 - 641 ft (*Fld. Cntrl.*)
 W.F. George: 187.5 - 190 ft (*Normal*)
 185 ft (*Minimum*)
 J. Woodruff: **76.5 - 77.5 ft**

Water Demands:

2050

Flow Requirements:

Chattahoochee: **MIOP**

Reservoir Elevation Ranges

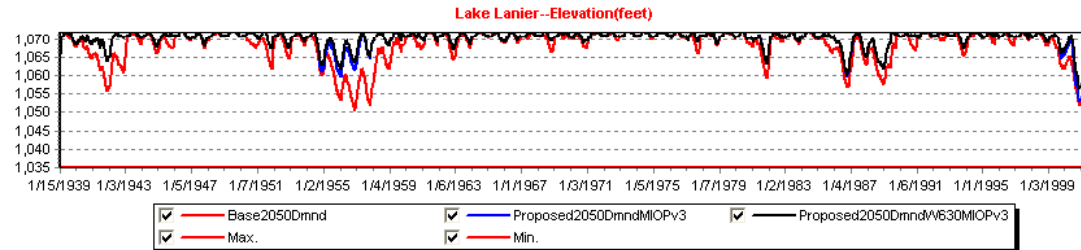
West Point: **630 - 635 ft**
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 185 ft (*Minimum*)
 J. Woodruff: **76.5 - 77.5 ft**

Water Demands:

2050

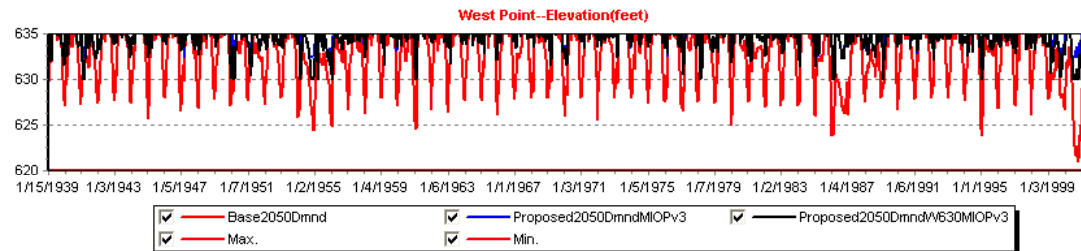
Modified IOP Assessments (IOP/2050/621; MIOP/2050/632.5; MIOP/2050/630)

Lanier

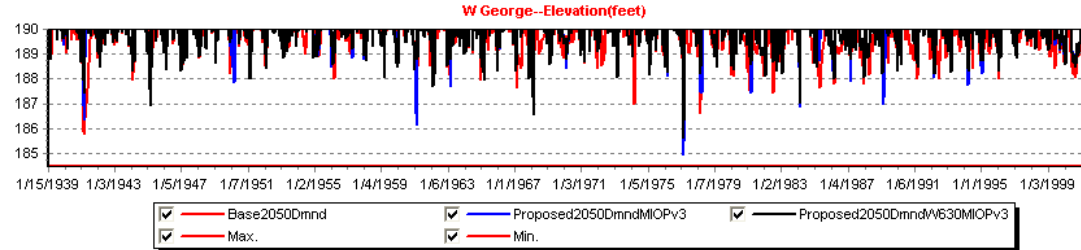


MIOP/630 WP
MIOP/632.5 WP
IOP/621 WP

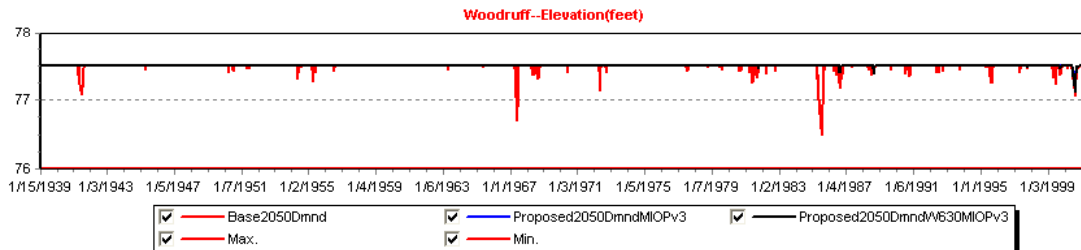
W. Point



George



Woodruff

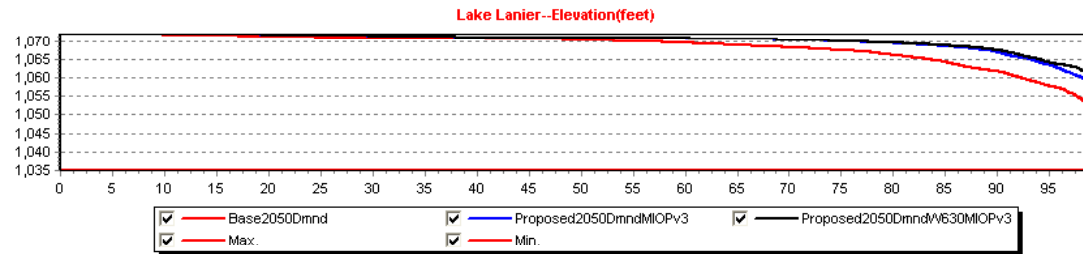


- Lanier: Up to 10 ft deeper drawdowns under IOP/621 than either MIOP.
- West Point: MIOP levels are always higher than 630 or 632.5.

Modified IOP Assessments

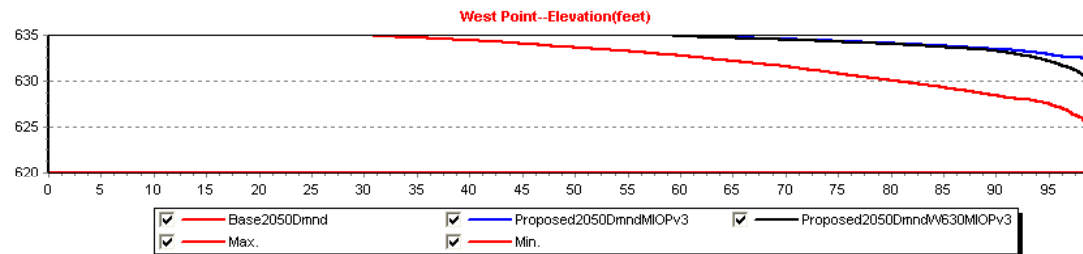
(IOP/2050/621; MIOP/2050/632.5; MIOP/2050/630)

Lanier

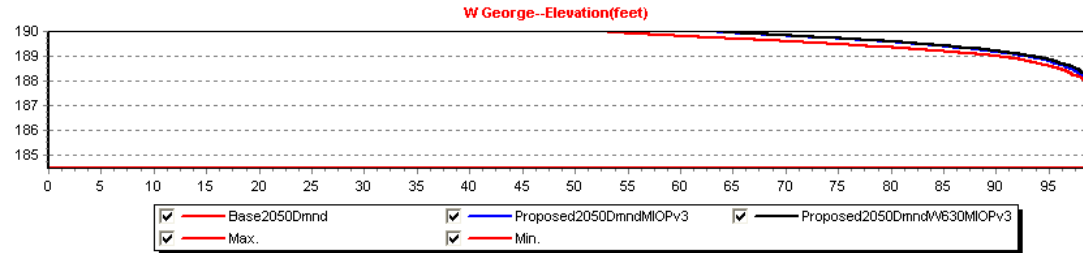


→ MIOP/630 WP
→ MIOP/632.5 WP
→ IOP/621 WP

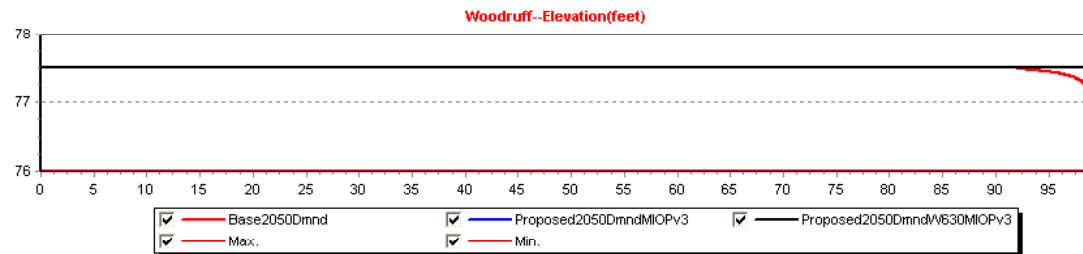
W. Point



George



Woodruff



- Lanier: Up to 10 ft deeper drawdowns under IOP/621 than either MIOP.
- West Point: MIOP levels are always higher than 630 or 632.5.

IOP/2007

Flow Requirements:

Chattahoochee: **IOP**

Reservoir Elevation Ranges:

West Point: **621 - 635 ft**
 635 - 641 ft (*Fld. Cntrl.*)
 W.F. George: 187.5 - 190 ft (*Normal*)
 185 ft (*Minimum*)
 J. Woodruff: **76 - 77.5 ft**

Water Demands:

2007

MCWC-1/2050

Flow Requirements:

Chattahoochee: **MIOP**

Reservoir Elevation Ranges

West Point: **632.5 - 635 ft**
 635 - 641 ft (*Fld. Cntrl.*)
 W.F. George: 187.5 - 190 ft (*Normal*)
 185 ft (*Minimum*)
 J. Woodruff: **76.5 - 77.5 ft**

Water Demands:

2050

MCWC-2/2050

Flow Requirements:

Chattahoochee: **MIOP**

Reservoir Elevation Ranges

West Point: **630 - 635 ft**
 635 - 641 ft (*Fld. Cntrl.*)
 W.F. George: 187.5 - 190 ft (*Normal*)
 185 ft (*Minimum*)
 J. Woodruff: **76.5 - 77.5 ft**

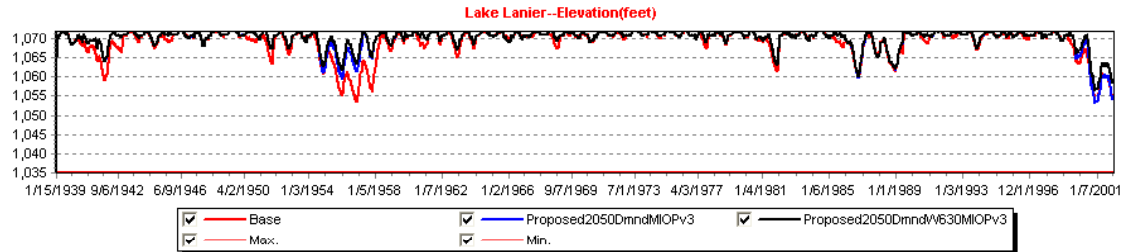
Water Demands:

2050

Modified IOP Assessments

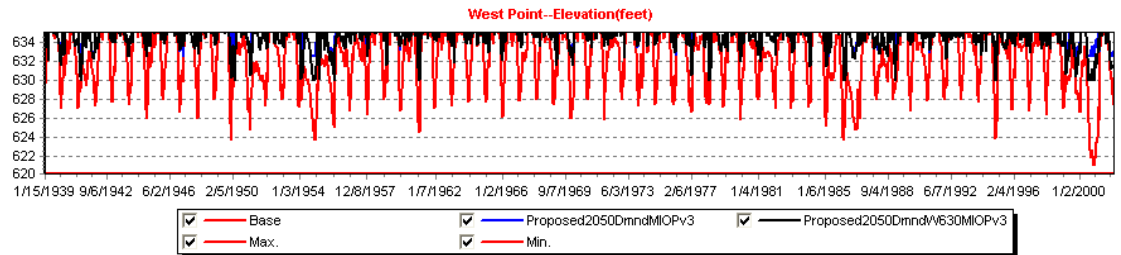
(IOP/2007/621 WP; MIOP/2050/632.5 WP; MIOP/2050/630 WP)

Lanier

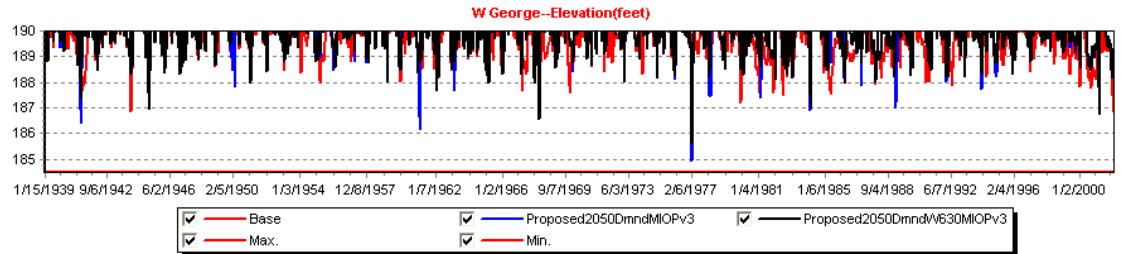


MIOP/630 WP
MIOP/632.5 WP
IOP/621 WP

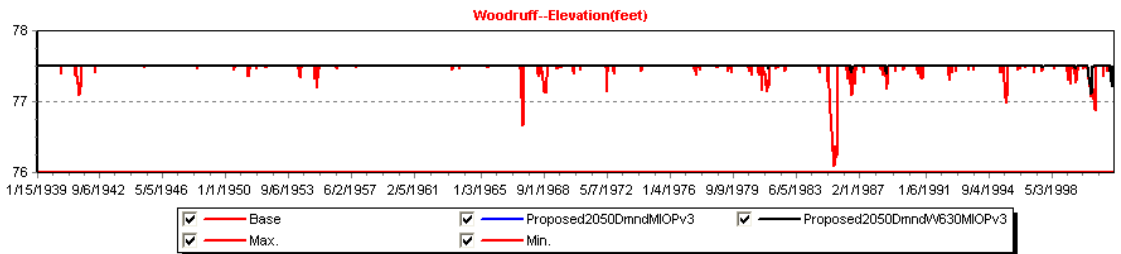
W. Point



George

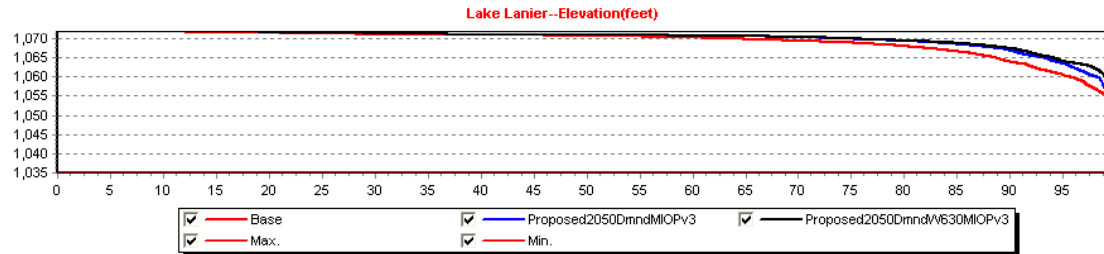


Woodruff



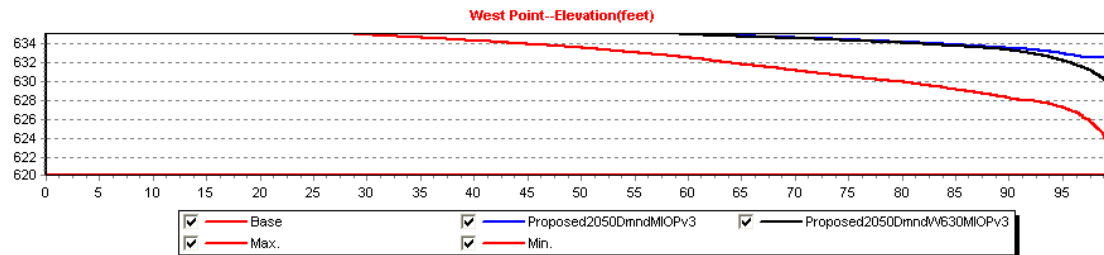
- Lanier: MIOP/2050 scenarios keep higher lake levels than IOP/2007.
- West Point: MIOP levels are always higher than 630 or 632.5.

Lanier

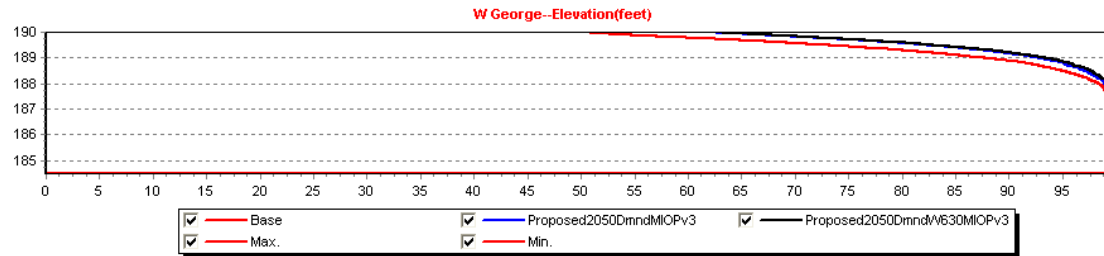


MIOP/630 WP
MIOP/632.5 WP
IOP/621 WP

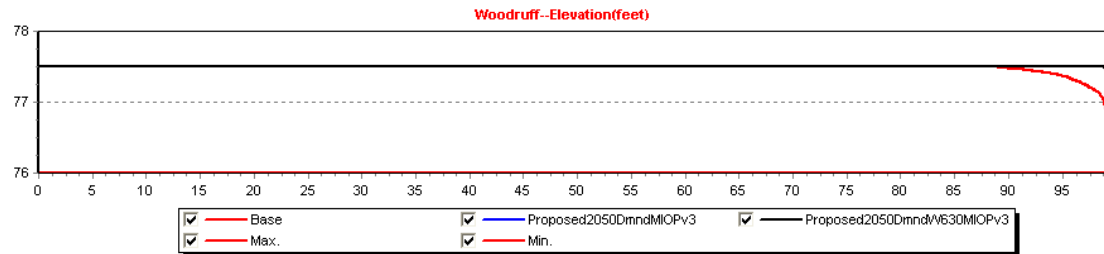
W. Point



George

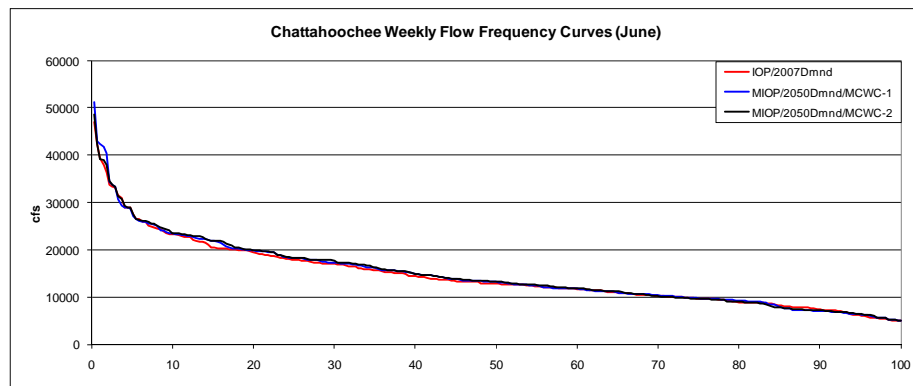
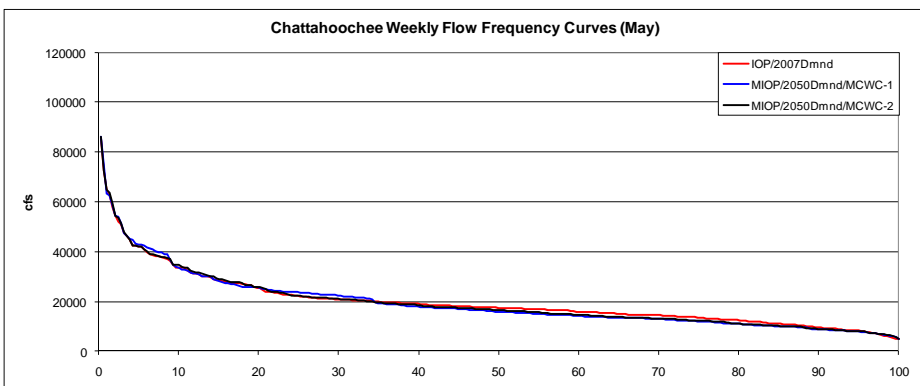
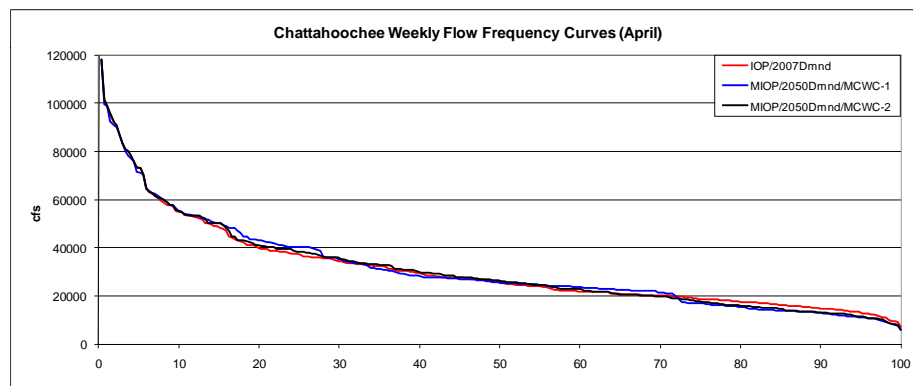
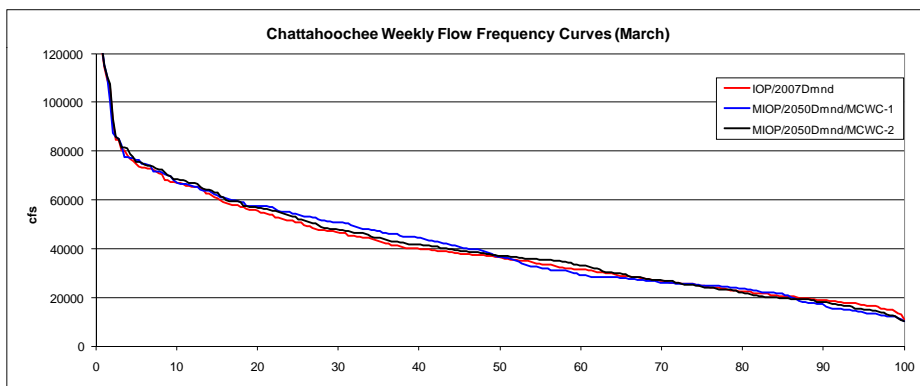
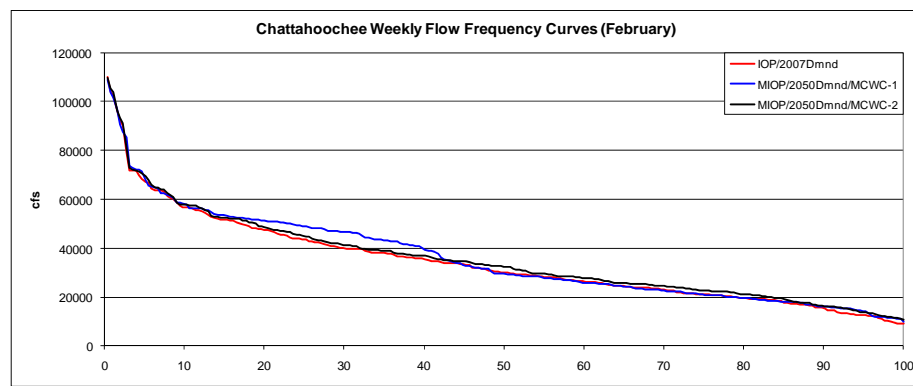
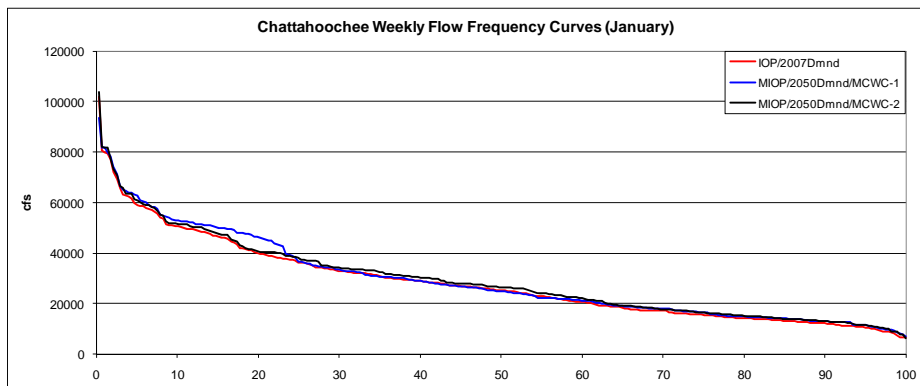


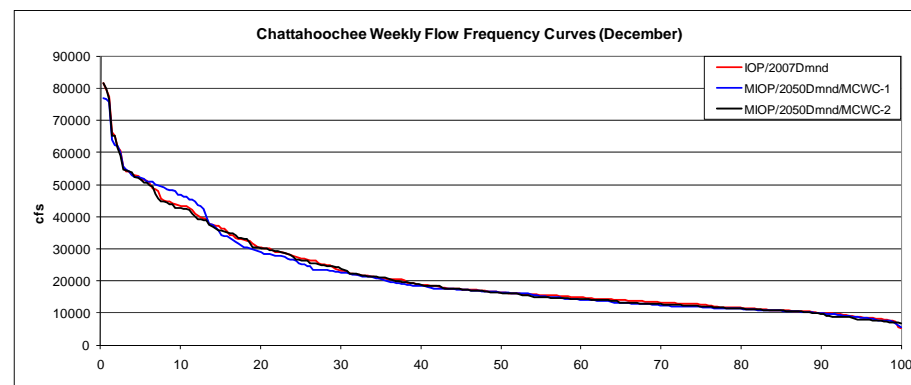
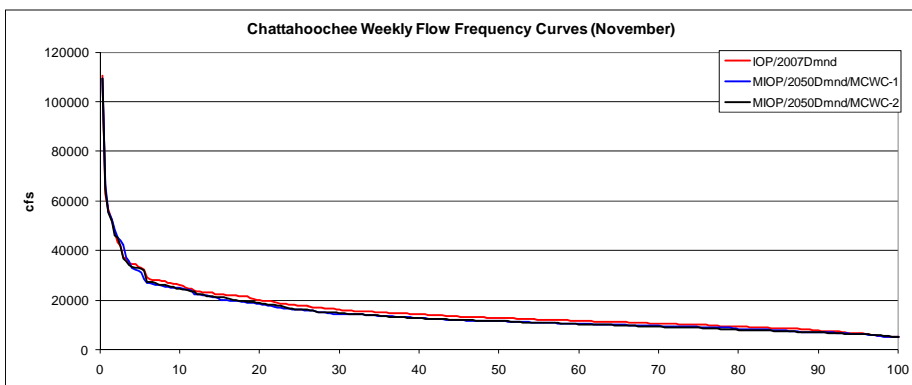
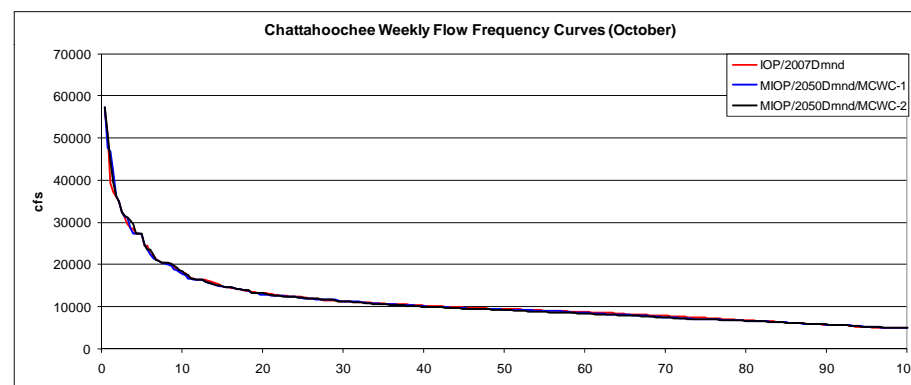
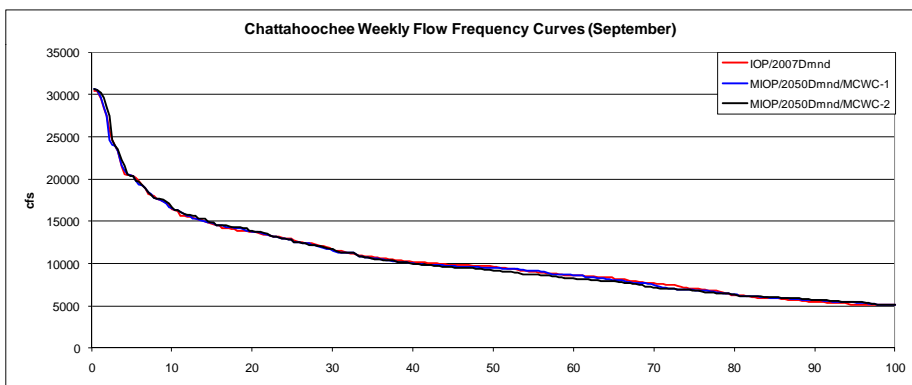
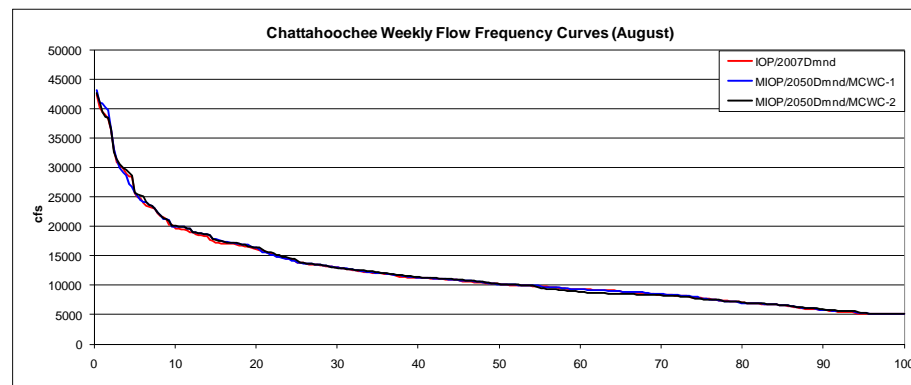
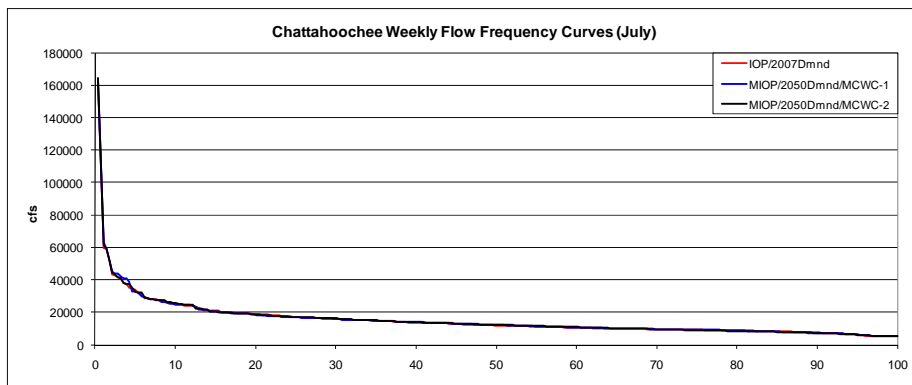
Woodruff

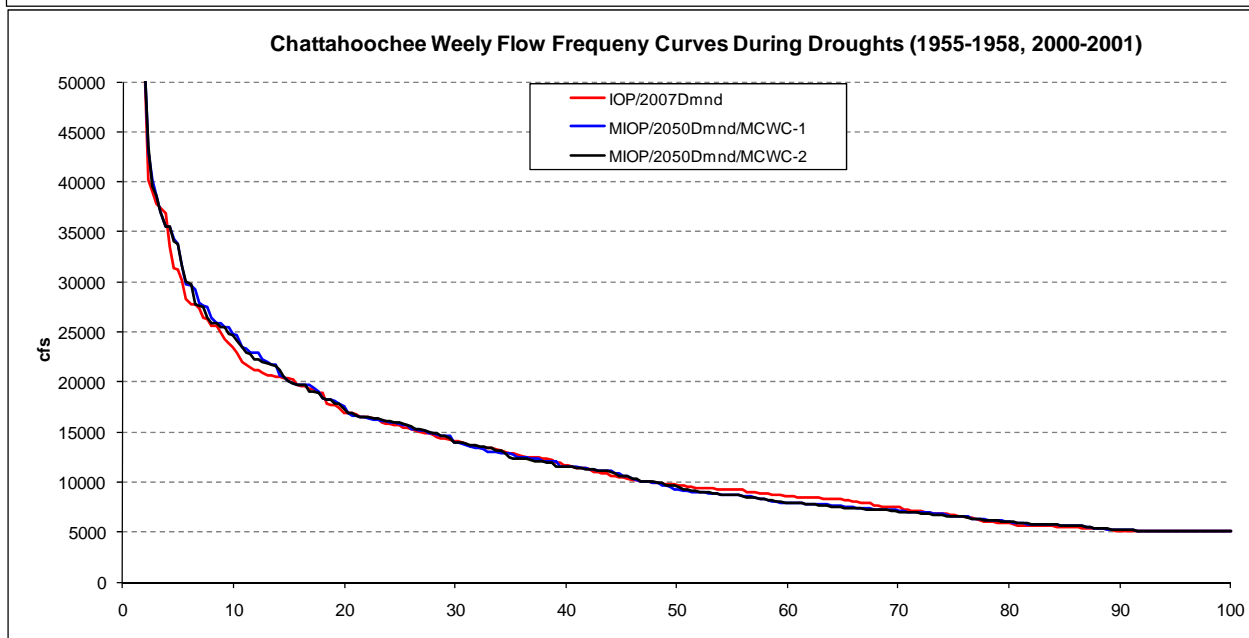
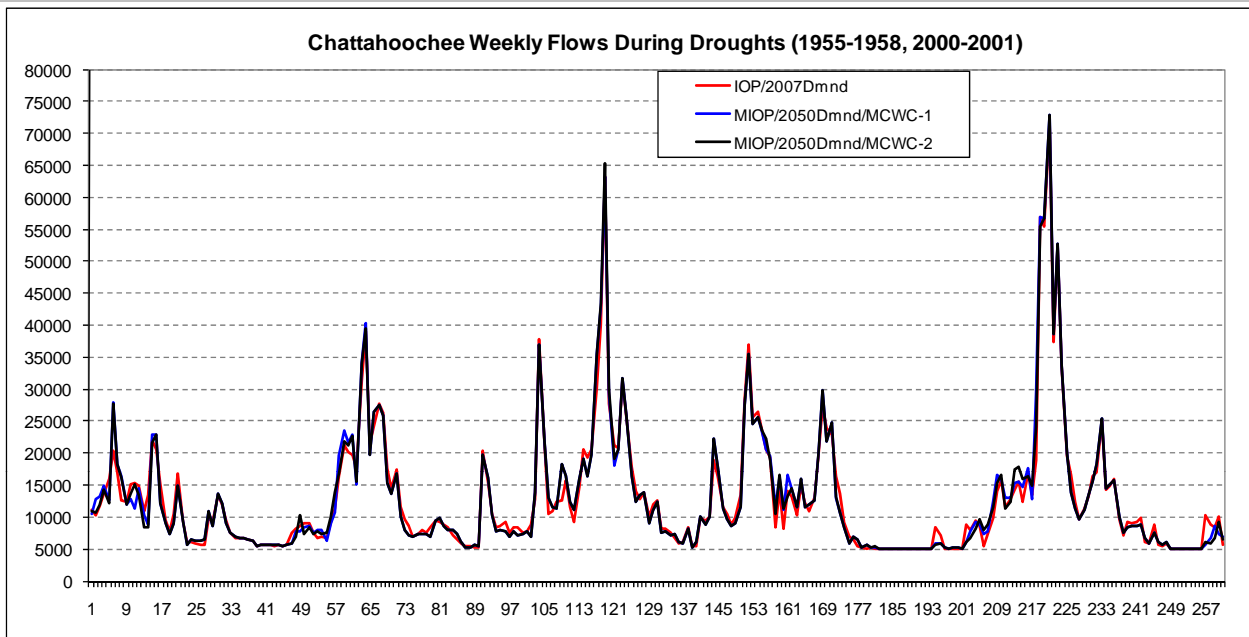


- Lanier: MIOP/2050 scenarios keep higher lake levels than IOP/2007.
- West Point: MIOP levels are always higher than 630 or 632.5.

- Raising the West Point minimum level under the **existing IOP** and 2007 demands would cause **5-9 ft** deeper drawdowns at Lanier. Under 2050 demands, Lanier lake level impacts would become more pronounced (**~9-11 ft**). **No other adverse impacts are expected (i.e., with respect to instream flows, water demand targets, or hydropower).**
- Raising the West Point minimum level under the **Modified IOP** yields significant benefits (**5-10 ft higher levels**) for Lanier as well as for West Point (**compared to the IOP**).
- **The Modified IOP enables the lakes to recover faster after severe droughts, reducing the risk of follow-up droughts for all ACF stakeholders.**
- **The Chattahoochee gage (FL) flow distributions under the Modified IOP and the IOP are not appreciably different. As such, the MIOP is not expected to impact the Apalachicola ecology and fisheries more adversely than the IOP. Comparisons of the Chattahoochee flows downstream of Woodruff under IOP and MIOP are presented next.**
- The Modified IOP can be further fine-tuned.









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