

APPENDIX I DRAFT FINAL OPERATIONAL PLAN

Appendix I
Draft Environmental Impact Report

Reservoir Dam Water Storage and Fish Passage
Improvement Project

First Herring Brook
Draft Final Operational Plan

July 15, 2019

Prepared by the North and South Rivers Watershed Association and MassBays

First Herring Brook

Draft Final Operational Plan

July 2019

1. Background

The First Herring Brook draft final operational plan (DFOP) provides guidance to the Town of Scituate Water Division (SWD) to manage seasonal streamflows and operate the Old Oaken Bucket Pond and Reservoir fish ladders for aquatic community needs while maintaining adequate water supply for Town needs. The DFOP updates the First Herring Brook Interim Operational Plan (IOP), which is provided in Attachment 1, and is based on a series of reports (see Section 9.) detailing the Town's water system and investigating the impacts of streamflow releases on herring migration, resident aquatic communities, and water supply in First Herring Brook. This plan will be updated and implemented once the proposed infrastructure improvements have been completed at Reservoir Dam. Until that time, the 2015 Update of the Interim Operational Plan (Attachment 2) should be used.

2. Measuring Streamflow

This plan sets streamflow and fish ladder flow goals downstream of the Old Oaken Bucket Pond and the Scituate Reservoir, to be evaluated by measurements at the gages described below.

- **First Herring Brook at Eisenhower Lane (Downstream of Reservoir).** As of July 2015 this site includes a staff gage for field water level readings and a pressure transducer which records water levels at regular intervals (every 15 minutes). This site is located roughly 600 feet downstream of the Reservoir.
- **First Herring Brook at Country Way (Downstream of Old Oaken Bucket Pond).** As of July 2015 this site includes a pressure transducer upstream of Country Way which is connected to Scituate's SCADA system such that SWD may read water levels from inside the treatment plant. The site also includes a staff gage and a pressure transducer (which logs water levels every 15 minutes) downstream of Country Way.

The Massachusetts Division of Ecological Restoration (DER) maintains rating curves at both sites to estimate streamflow from water depth at the staff gage, making one to two annual field measurements to verify that the relationship is still accurate. Rating curves are sensitive to changes in the shape of the channel, which may occur due to sediment movement, beaver dams, or other factors. Contact DER or the North and South Rivers Watershed Association (NSRWA) for assistance if any such conditions are noted. DER periodically downloads transducer data, and River Instream Flow Stewards (RIFLS) volunteers read both staff gages and enter data at www.rifls.org.

3. Streamflow Guidelines

The streamflow guidelines shown in the table below are based on estimated low flows for each bioperiod (i.e., April-May). The dams' outlet structures may be adjusted to meet these guidelines. Fish ladders should be managed to provide the water depths indicated during migration periods in spring and fall. If inadequate water is available to meet these targets, SWD staff are encouraged to consult with NSRWA staff.

Streamflow guidelines were originally developed for the staff gage downstream of Country Way. However, SWD has since installed the transducer upstream of Country Way and staff have been applying an offset to the water levels presented in Version 1 of this plan. This version formally sets adjusted targets for SWD's transducer. DER and NSRWA staff compared continuous data collected at the Country Way site by the DER and SWD loggers over a two-month period in 2015, and found a fairly consistent offset of 1.08 feet

between water levels measured by the two loggers. That offset was applied to the targets set in Version 1, to create the updated table shown below.

Table 1. Interim Streamflow Guidelines, updated June 2019.

Bioperiod	Country Way		Eisenhower Lane	
	Streamflow (cfs)	Water level, ft (in SCADA)**	Streamflow (cfs)	Water level, ft (at staff gauge)
Mar/Apr*	3.30	2.05	2.59	4.81
May*	2.56	2.00	2.59	4.81
Jun /Aug	0.36	1.68	0.24	3.92
Sep*/Oct*, Nov	0.44	1.70	0.31	3.93
Dec - Feb	2.85	2.02	2.23	4.77

*During these fish migration periods, the primary focus of releases should be to maintain appropriate water depths over fish ladder weirs. These depths are 8 inches in the spring across the entire weir and 5 inches in the notch in the fall at both ladders.

** For reference, water levels at the Country Way staff gage should be as follows: Mar/Apr 0.97, May 0.92, Jun/Aug 0.60, Sep-Nov 0.62, Dec-Feb 0.94

4. Release of Streamflow

Streamflow should be released in a manner that prevents flashy flows to the greatest extent possible, including slowly increasing flow rates using the updated SCADA system. There may be conditions in which the Reservoir flows may need to be augmented above the prescribed rates to ensure that the Old Oaken Bucket flows meet the targets.,

5. Operation of Fish Ladders

Old Oaken Bucket – During fish migration periods, the ladder should be operated with the board out of the top of the fish ladder. Flows should provide 8 inches of depth above the wooden weirs. In the fall, flows should provide 5 inches of depth through the weir notches.

Reservoir - Details will be included once Reservoir construction is completed.

6. Demand Management Guidelines

In Spring 2015, at the recommendation of the Scituate Water Resources Committee, the Scituate Water Commissioners adopted a number of changes to demand management. Those most pertinent to this plan are an expansion of the period during which automatic irrigation sprinklers use is restricted to May - September, and that when Scituate’s Reservoir falls to a level of El. 36.0 feet (ft.), which is 49% full, the SWD has the standing authority to implement a total outdoor watering ban; as in the IOP hey may curtail downstream flows when the Reservoir level falls to El. 32.0 feet. These levels will also change once the Reservoir improvements are complete – the water ban will go into place at El. 38.0 ft. (3.5 ft below the spillway) and the streamflow cutoff at El. 33.5 ft. (8 feet below the spillway, no change). Note that these levels assume that the existing normal pool with the unimproved Reservoir Dam spillway fixed crest is at El. 40.0 feet and the proposed normal pool with the spillway gate fully closed is at El. 41.5 feet. El. 40.0 ft correspondence to El. 38.0 ft North American Vertical Datum 1988 (NAVD88).

7. Adaptive Management

SWD, NSRWA, and DER staff have made a number of adjustments to operations, based on experience with adjusting outflows and observing results, challenges due to dry conditions, and review of streamflow data. Partners will continue to adaptively manage operations of the Reservoir and Old Oaken Bucket Pond to

achieve streamflow and water supply goals, including using the NSRWA Streamflow Management Tool to provide feedback on projected Reservoir supply and days until a potential water ban or streamflow cutoff.

8. Other Resources

The streamflow guidelines are based on multiple WEAP modeling efforts over the past decade. These modeling results are not included but if needed can be requested from NSRWA or DER. DER periodically reviews data collected at the two stream gauging stations, to assess the degree to which streamflows meet the targets laid out in this plan. For the latest assessment please contact DER staff.

9. References

Corona Environmental Consulting, LLC. June 2017. *Reservoir Dam Water Storage Modeling, Contract 17-WA-7*. Prepared for the Town of Scituate Massachusetts.

Kearns, M. June 2013. *Improving Fish Passage and Environmental Stream Flows In First Herring Brook, Scituate, MA*. Prepared for the North and South Rivers Watershed Association.

Kearns, M. June 30, 2012. *First Herring Brook Priority Project WEAP Model Scenarios*. Prepared for the North and South Rivers Watershed Association.

Kearns, M. June 23, 2011. *First Herring Brook Interim Operational Plan*. Prepared for the North and South Rivers Watershed Association and the Town of Scituate, MA.

The Massachusetts Division of Ecological Restoration. May 20, 2010. *First Herring Brook Environmental Flow Project: Addendum Report*. A Joint Project of the Scituate Water Resources Committee and the North and South Rivers Watershed Association.

MassGIS. August 2015. *Surficial Geology (1:24,000)*. GIS shapefile retrieved May 10, 2017. <http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/sg24k.html>

The Nature Conservancy, the Stockholm Environment Institute and the Massachusetts Division of Ecological Restoration. January 12, 2010. *First Herring Brook Environmental Flows Project, Scituate, Massachusetts*. A Joint Project of the Scituate Water Resources Committee and the North and South Rivers Watershed Association.

List of Attachments

Attachment 1 First Herring Brook Interim Operational Plan – August 23, 2011

Attachment 2 First Herring Brook Interim Operational Plan, Version 2 – July 20, 2015

First Herring Brook Interim Operational Plan, Version 2

Version 2: July 20, 2015, updated by Laila Parker, Massachusetts Division of Ecological Restoration, River Instream Flow Stewards Program.

Version 1: August 23, 2011, prepared by Margaret Kearns for the North and South Rivers Watershed Association and the Town of Scituate, MA under a grant from the Massachusetts Division of Ecological Restoration.

1. Background

This plan provides guidance to the Town of Scituate Water Division (SWD) to manage seasonal streamflows and operate the Old Oaken Bucket Pond fish ladder for aquatic community needs while maintaining adequate water supply for Town needs. The plan is based on a series of reports detailing the Town's water system and investigating the impacts of streamflow releases on herring migration, resident aquatic communities, and water supply in First Herring Brook.¹ The Interim Operational Plan relies on the infrastructure existing at the time of publication; a companion Final Operational Plan may be used once infrastructure modifications have been made at the Reservoir.²

2. Measuring Streamflow

This plan sets streamflow and fish ladder flow goals downstream of the Old Oaken Bucket Pond and the Scituate Reservoir, to be evaluated by measurements at the gages described below.³

- **First Herring Brook at Eisenhower Lane (Downstream of Reservoir).** As of July 2015 this site includes a staff gage for field water level readings and a pressure transducer which records water levels at regular intervals (every 15 minutes). This site is located roughly 600 feet downstream of the Reservoir.
- **First Herring Brook at Country Way (Downstream of Old Oaken Bucket Pond).** As of July 2015 this site includes a pressure transducer upstream of Country Way which is connected to Scituate's SCADA system such that SWD may read water levels from inside the treatment plant. The site also includes a staff gage and a pressure transducer (which logs water levels every 15 minutes) downstream of Country Way.

The Massachusetts Division of Ecological Restoration (DER) maintains rating curves at both sites to estimate streamflow from water depth at the staff gage, making one to two annual field measurements to verify that the relationship is still accurate. Rating curves are sensitive to changes in the shape of the channel, which may occur due to sediment movement, beaver dams, or other factors. Contact DER or the North and South Rivers Watershed Association (NSRWA) for assistance if any such conditions are noted. DER periodically downloads transducer data, and River Instream Flow Stewards (RIFLS) volunteers read both staff gages and enter data at www.rifls.org.

3. Streamflow Guidelines

The streamflow guidelines shown in the table below are based on estimated low flows for each bioperiod (i.e., April-May). The dams' outlet structures may be adjusted to meet these guidelines. Fish ladders should be managed to provide the water depths indicated during migration periods in spring and fall. If inadequate water is available to meet these targets, SWD staff are encouraged to consult with NSRWA staff.

¹ The Nature Conservancy, the Stockholm Environment Institute and the Massachusetts Division of Ecological Restoration. January 2010. *First Herring Brook Environmental Flows Project, Scituate, Massachusetts*; Massachusetts Division of Ecological Restoration. May 2010. *First Herring Brook Environmental Flow Project: Addendum Report*. Both reports produced for the Scituate Water Resources Committee and the North and South Rivers Watershed Association, Scituate, Massachusetts.

² Tetra Tech, Inc., June 2014. *Final Preliminary Design Memorandum for Reservoir Dam Fish Passage Project*. Produced for the Town of Scituate.

³ Note that streamflow guidelines for the Country Way site include estimated flows from the Satuit Meadow tributary that enters the river just downstream of Old Oaken Bucket Pond dam.

Streamflow guidelines were originally developed for the staff gage downstream of Country Way. However, SWD has since installed the transducer upstream of Country Way and staff have been applying an offset to the water levels presented in Version 1 of this plan. This version formally sets adjusted targets for SWD’s transducer. DER and NSRWA staff compared continuous data collected at the Country Way site by the DER and SWD loggers over a two-month period in 2015, and found a fairly consistent offset of 1.08 feet between water levels measured by the two loggers. That offset was applied to the targets set in Version 1, to create the updated table shown below.

Table 1. Interim Streamflow Guidelines, updated July 2015. **Numbers in bold text** indicate primary targets for each bioperiod.

Bioperiod	Country Way			Eisenhower Lane	
	Streamflow (cfs)	Water level (in SCADA)**	Fish ladder (inches)	Streamflow (cfs)	Water level (at staff gage)
March	3.78	2.09		2.56	4.80
April – May*	3.78	2.09	8	2.56	4.80
June – August	0.39	1.69		0.22	4.13
Sep – Oct*	0.45	1.71	5	0.25	4.16
November	0.45	1.71		0.25	4.16
Dec - Feb	3.15	2.05		2.13	4.75

*During these fish migration periods, the primary focus of releases should be to maintain appropriate water depths over fish ladder weirs.

** For reference, water levels at the Country Way staff gage should be as follows. March - May: 1.01 feet, June – August: 0.61 feet, September – November: 0.63 feet, December – February: 0.97 feet.

4. Demand Management Guidelines

In Spring 2015, at the recommendation of the Scituate Water Resources Committee, the Scituate Water Commissioners adopted a number of changes to demand management. Those most pertinent to this plan are an expansion of the period during which automatic irrigation sprinklers use is restricted to May - September, and that when Scituate’s Reservoir falls to a level of 36 feet (49% full), the SWD has the standing authority to implement a total outdoor watering ban; as before they may curtail downstream flows when the Reservoir falls to 32 feet.⁴

5. Adaptive Management

SWD, NSRWA, and DER staff have made a number of adjustments to operations, based on experience with adjusting outflows and observing results, challenges due to dry conditions, and review of streamflow data; many of these changes are reflected in this Version 2 (others include, for example, installed of notched weirs at the Old Oaken Bucket fish ladder to improve achievement of sufficient depths for passage). Partners will continue to adaptively manage operations of the Reservoir and Old Oaken Bucket Pond to achieve streamflow and water supply goals.

6. Other Resources

- Version 1 of the Interim Operational Plan included results and discussion of eight WEAP model scenarios run to identify the level of streamflow and fish ladder flow releases that could be made with the current system without compromising the reliability of the public water supply. Because by 2015 the SWD has expertise and understanding in the implementation of these streamflow guidelines, the modeling results are not included in Version 2 but if needed can be requested from NSRWA or DER.
- DER periodically reviews data collected at the two streamgaging stations, to assess the degree to which streamflows meet the targets laid out in this plan. For the latest assessment please contact DER staff.

⁴ Note, in Version 1 of the Interim Operational Plan (2011), the guidelines were as follows: Memorial Day – Labor Day: Automatic irrigation systems restricted to watering once per week. Reservoir water level at 35 feet (60 inches below spillway): Enact total outdoor watering ban. Reservoir water level at 32 feet (96 inches below spillway): Shut off downstream flow.

First Herring Brook Interim Operational Plan

August 23, 2011

M. Kearns

Prepared for the North and South Rivers Watershed Association and the Town of Scituate, MA
under a grant from the Massachusetts Division of Ecological Restoration.

1. Background

This plan provides guidance to the Town of Scituate Water Department to manage seasonal streamflows and operate the Old Oaken Bucket pond fish ladder while maintaining adequate water supply for Town needs. The plan is based on a series of reports detailing the Town's water system and investigating the impacts of streamflow releases on herring migration, resident aquatic communities and water supply in First Herring Brook. A Final Operational Plan was also developed, which relies on new fish ladders, the installation of weirs and a new water source. The Interim Operational Plan relies only on the infrastructure existing at the time of publication and for this reason will result not achieve streamflow goals as often as the final plan. Previous results have shown that the existing fish ladder at the Reservoir cannot function to pass fish effectively but the current Old Oaken Bucket Pond fish ladder may be functional if operated correctly. For this reason, flow guidelines are only provided for the Old Oaken Bucket Pond fish ladder in the Interim Operational Plan. For more details on project goals and model scenarios see:

- The Nature Conservancy, the Stockholm Environment Institute and the Massachusetts Division of Ecological Restoration. January 12, 2010. "First Herring Brook Environmental Flows Project, Scituate, Massachusetts". Produced for the Scituate Water Resources Committee and the North and South Rivers Watershed Association, Scituate, Massachusetts.
- Massachusetts Division of Ecological Restoration. May 20, 2010. "First Herring Brook Environmental Flow Project: Addendum Report". Produced for the Scituate Water Resources Committee and the North and South Rivers Watershed Association, Scituate, Massachusetts.

2. Measuring Streamflow

2.1 Locations

- Downstream of the Reservoir at Eisenhower Ln.
- Downstream of Country Way (streamflow guidelines include estimated flows from the Satuit Meadow tributary that enters the river just downstream of the dam and upstream of Country Way).

2.2 Staff Gauges

A staff gauge was installed at Country Way and surveyed to a local benchmark to facilitate recovery of the rating curve if the gauge moves or is vandalized. The Eisenhower Ln staff gauge is already in place.

2.3 Rating Curves

Rating curves should be developed so that stream flow may be estimated from stage height (water depth at the staff gauge). The Eisenhower Ln site has already been rated. Downstream of Country Way, staff of the MA Division of Ecological Restoration will provide gauge installation and rating curve development assistance through the River Instream Flow Stewards Program (RIFLS). Rating curves are sensitive to changes in the shape of the channel, such as those caused by movement of large amounts of sediment during storms, and to backwater effects from downstream, such as beaver dams or other blockages. Consequently, both rating curves must be maintained with 1-2 annual field measurements of streamflow. Contact the MA DER or NSRWA for assistance in maintaining the rating curves or if any conditions affecting their accuracy are noted.

2.4 Data Loggers

Automated water depth loggers will be deployed at both sites to record water depth at regular intervals. Loggers will be maintained and downloaded by DER and/or NSRWA staff periodically. (The loggers will not typically be helpful in day-to-day management because they require a computer interface for viewing data.) The depth data will be converted to streamflow values using the sites'

rating curves and used to evaluate the success of the Interim Operational Plan. Similar loggers may be installed in the future with wireless data transmission to the Water Department's SCADA system so that flow at both sites may be monitored from the treatment plant.

3. Streamflow Guidelines

Interim streamflow guidelines are based on minimum “BioQ90” flows, or 90th percentile monthly flows (low flows) for each bioperiod. Flows exceeding the minimum guidelines should be common, occurring naturally 90% of the time. If flow falls below the minimum guideline the low flow outlet at the dam should be opened to provide the minimum flow. Flow in the river will generally take 5–15 minutes to stabilize once an adjustment is made at the outlet structure. The Eisenhower Lane site may take slightly longer to respond since it is about 200 meters downstream of the dam. Fish ladders should be managed to provide the water depths indicated in spring and fall only. If inadequate water depth is available to meet the depth requirements the ladder should be closed with boards and river flow maintained through the low level outlet structures.

Table 1. Interim Streamflow Guidelines

Bioperiod	Country Way (downstream of Old Oaken Bucket Pond)			Eisenhower Ln. (downstream of Reservoir)	
	River (cfs)	Staff Gauge (ft)	Fish Ladder** (inches)	River (cfs)	Staff Gauge (ft)
Mar	3.78	1.01	0	2.56	4.80
Apr – May	[3.78**]	1.01	8 [”]	2.56	4.80
Jun – Aug	0.39	0.61	0	0.22	4.13
Sep – Oct	[0.45**]	0.63	5 [”]	0.25	4.16
Nov	0.45	0.63	0	0.25	4.16
Dec – Feb	3.15	0.97	0	2.13	4.75

April - May, Sept - Oct - Manage using GREEN inches over fish ladders or weirs unless there is not enough water. If drought conditions are occurring then use staff gage heights to maintain minimum streamflows in river.

** Eight inches of depth equals 5.2 cfs and five inches of depth equals 2.6 cfs. Because these flows exceed the river flow goals all downstream releases during the migration seasons should be made through the fish ladder.

4. Demand Management Guidelines

Memorial Day - Labor Day: In-ground irrigation systems restricted to watering once per week.

Reservoir water level 60 inches (5 feet) below spillway: Enact total outdoor watering ban.

Reservoir water level 96 inches (8 feet) below spillway: Shut off downstream flow.

5. Record Keeping

The following data should be recorded at each visit:

Date _____

Precipitation (inches) _____

Time _____

Outdoor watering ban in effect YES / NO

Eisenhower Ln
(downstream of Reservoir)

Country Way
(downstream of Old Oaken Bucket Pond)

Water level (inches below spillway) _____

Stage height (ft) _____

Fish ladder boards in or out _____
Low level outlet % and time open _____

6. Adaptive Management

Results of the first year of operation will be compared to bioperiod streamflow and fish ladder flow goals by staff of the North and South Rivers Watershed Association. Water Department staff will provide input on any impacts to the water supply system. This information will be shared with the Water Department and Water Resources Committee and changes may be made as necessary.

Appendix A. Interim Operational Plan WEAP Scenarios

A.1 Scenarios

Eight new WEAP model scenarios were run to identify the level of streamflow and fish ladder flow releases that could be made with the current system without compromising the reliability of the public water supply. No new fish ladders, weirs or additional water sources were used in the Interim Operational Plan scenarios.

Streamflow

The BioQ90 streamflows for each bioperiod were included in the new scenarios, except for “Interim -1”, which was run for comparative purposes with no streamflow requirement. To ensure the reliability of the water system, scenarios 4-6 included a Reservoir threshold trigger to shut off the BioQ90 flows at 32 or 34 feet elevation (96 inches/8 feet or 72 inches/6 feet below the spillway, respectively).

Fish Ladders

In all of the scenarios except “Interim -1”, the existing Reservoir fish ladder is shut off entirely and only the Old Oaken Bucket Pond fish ladder functions. In “Interim -1” neither fish ladder is actively managed. The Old Oaken Bucket Pond fish ladder provides at least 8 inches of water (5.2 cfs) in April and May for in-migration and at least 5 inches of water (2.6 cfs) in September and October for out-migration of herring.

Irrigation Restriction

The Town’s recently passed in-ground irrigation restriction limiting in-ground irrigation to one day per week was assumed to reduce demand for water from June–August by 0.4 mgd with a minimum summer water use equal to average winter demand (1.31 mgd). The 0.4 mgd water savings estimate is based on the savings documented by the Scituate Water Department in the summer of 2010 when an odd/even watering restriction was declared. Scenario “Interim 3” included an expanded irrigation restriction season from May - September based on the months when demand increases significantly above average winter demand.

Total Outdoor Water Ban

When the Reservoir water level drops more than 60” (5 feet) below the spillway current policy dictates that a total outdoor watering ban is declared. The total watering ban was modeled to reduce water use to average winter water use levels (1.31 mgd), conservatively based on actual water use of 1.00 mgd that was documented during the 2010 total outdoor watering ban. In the “Interim 2” scenario, the threshold for declaring a total outdoor watering ban was modeled at 36 inches (3 feet) below the spillway.

Table A.1 Interim Operational Plan WEAP Scenarios

Shaded boxes indicate active scenario components.

Scenario Description:	Interim -1	Interim 0	Interim 1	Interim 2	Interim 3	Interim 4	Interim 5	Interim 6
OOB Fish Ladder	spill only							
BioQ90 Streamflow						> 32 ft	> 32 ft	> 34 ft
Irrigation Restriction Jun – Aug					May–Sep			
Total Outdoor Ban < 35 ft Reservoir Elevation				< 37 ft				

A.2 Results

Water Supply

The ability to provide for the Town's water supply needs was determined by examining Reservoir water level elevations and unmet demand values.

Scenario "Interim -1", with no streamflow or fish ladder flow requirements, was able to meet the town's 1999-2007 average water demand of 543 million gallons per year.

"Interim 0", which included streamflow and fish ladder flow requirements but no demand management components, resulted in many instances of reservoir failure and fell short of meeting the Town's water needs by an average 30 million gallons per year.

"Interim 1" represents the current condition, with the irrigation restriction in place along with streamflow and fish ladder flow requirements. This scenario also resulted in reservoir failure, but much less frequently, with an unmet demand of only 3 million gallons per year.

"Interim 2", with a higher Reservoir trigger for the total outdoor water ban, also resulted in reservoir failure during the drought of record and fell short of meeting the Town's water needs by 1 million gallons per year.

"Interim 3" included a longer irrigation restriction season and also resulted in reservoir failure during the drought of record and an unmet demand of 3 million gallons per year.

"Interim 4" and "Interim 6" both included streamflow shutoff triggers and met the Town's water supply needs with no instances of reservoir failure. Both scenarios save about 53 million gallons per year through use of the irrigation restriction and total outdoor water ban.

"Interim 5" was run to determine whether the streamflow cutoff alone would result in the ability to meet water demands during the drought of record without demand management practices in place. It resulted in reservoir failure and an unmet demand of 17 million gallons per year.

Streamflow

The BioQ90 minimum streamflows were met in all scenarios where they were required (0-6). Additional streamflow targets were established by the stakeholder group during the initial modeling effort and were generally based on bioperiod median flows. In general, all of the scenarios produced similar streamflow results. Minimum flows were met and zero flow events were virtually eliminated, with the exception of one period during the drought of record for scenarios 4-6. Maintaining median bioperiod flows remains a challenge, particularly in the summer and fall months.

Fish Ladder Flow

All of the scenarios resulted in successful fish ladder operation (> 8 inches of water) 83-86% of the time. However, fall fish ladder success rates (> 6 inches of water) ranged from 13-21%. Thus, the Interim Operational Plan is unlikely to support juvenile herring outmigration on a sustainable basis.

Streamflow, fish ladder and water supply results are summarized quantitatively in Table A.2 below. Shaded boxes in the Scenario description section indicate model components that are included in the scenario. Shaded boxes in the rest of the table indicate areas where scenarios do not meet the water supply or flow goals established by the stakeholder group during the initial modeling process. Lighter shading indicates

areas where scenarios fall short of the goals to a lesser degree.

Scenario Description:	Interim -1	Interim 0	Interim 1	Interim 2	Interim 3	Interim 4	Interim 5	Interim 6	Natural
OOB Fish Ladder	spill only								
BioQ90 Streamflow						> 32 ft	> 32 ft	> 34 ft	
Irrigation Restriction Jun – Aug					May – Sep				
Total Outdoor Ban < 35 ft Reservoir Elevation				< 37 ft					

Water Supply:

Annual Supply Delivered (mgd)	543	513	488	473	475	491	527	492	na
Summer Use (mgd)	1.97	1.81	1.52	1.43	1.53	1.52	1.87	1.52	na
Annual Savings (mgd)		30	56	70	69	53	17	52	na
Annual Avg Unmet Demand (mgd)	0	30	3	1	2	0	17	0	na
Low est Reservoir Level (ft below spillway)	7.4	13	13	13	13	8.4	13	6.8	na

OOB Fish Ladder:

% Days Spring Ladder Flow s > 5.2 cfs (8 inches)	0	83	86	87	89	86	86	87	96
% Days Fall Ladder Flow s > 2.61 cfs (5 inches)	0	13	17	19	21	17	13	17	35

% 0 Flow Days:

OOB Mar-May	0	0	0	0	0	0	0	0	0
OOB Jun-Aug	1	0	0	0	0	0	1	1	0
OOB Sep-Nov	1	0	0	0	0	<1	1	<1	0
OOB Dec-Feb	0	0	0	0	0	0	0	0	0
Reservoir Mar-May	<1	0	0	0	0	0	0	0	0
Reservoir Jun-Aug	1	0	0	0	0	0	<1	0	0
Reservoir Sep-Nov	17	0	0	0	0	<1	2	1	0
Reservoir Dec-Feb	4	0	0	0	0	<1	1	<1	0

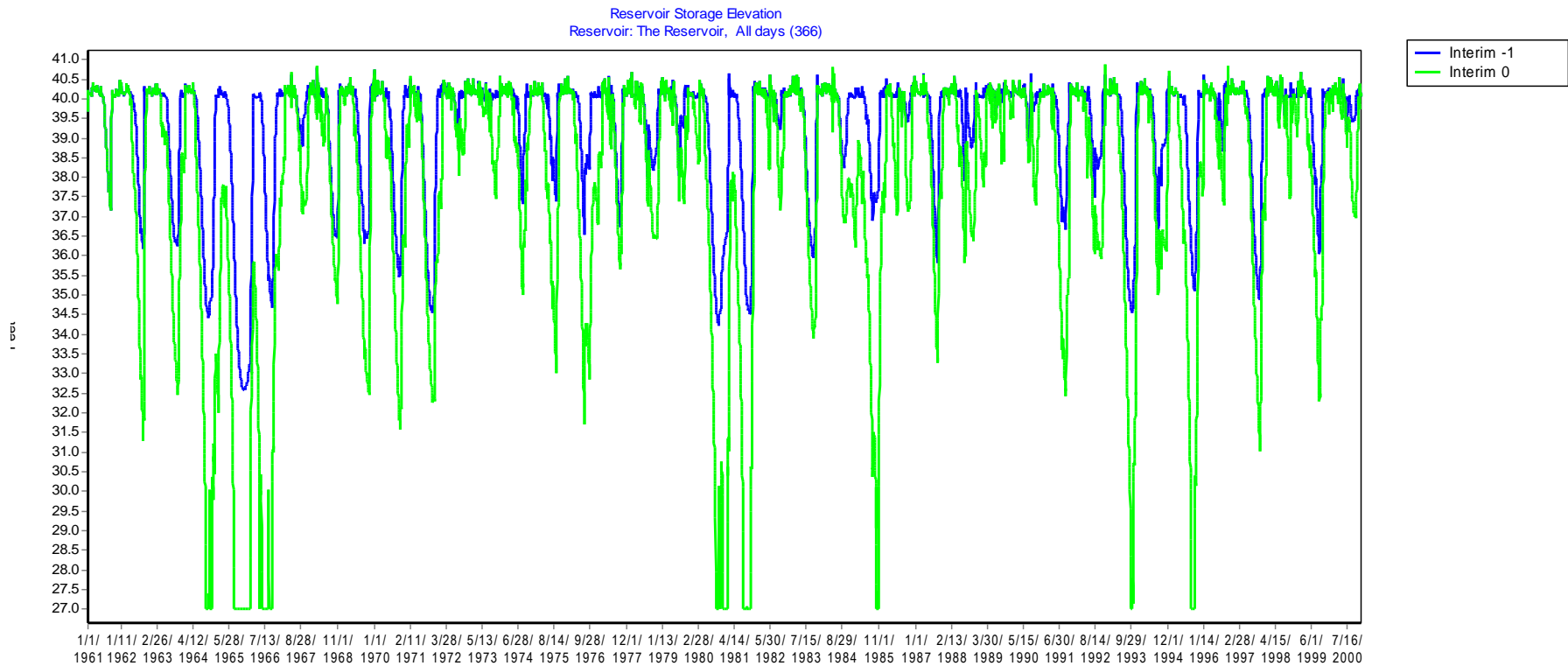
% of Natural Flow Goal Exceedance:

OOB Mar-Apr	80	77	77	78	77	77	77	78	100
OOB May	88	82	82	82	91	82	82	82	100
OOB Jun-Aug	24	20	25	25	25	25	20	25	100
OOB Sep-Nov	47	45	55	57	59	55	45	55	100
OOB Dec-Feb	80	69	72	73	73	72	70	72	100
Reservoir Mar-Apr	100	87	92	92	93	92	93	92	100
Reservoir May	100	73	126	125	126	106	125	126	100
Reservoir Jun-Aug	100	153	147	129	103	133	129	150	100
Reservoir Sep-Nov	100	65	73	70	59	69	70	71	100
Reservoir Dec-Feb	100	78	67	70	72	71	70	67	100

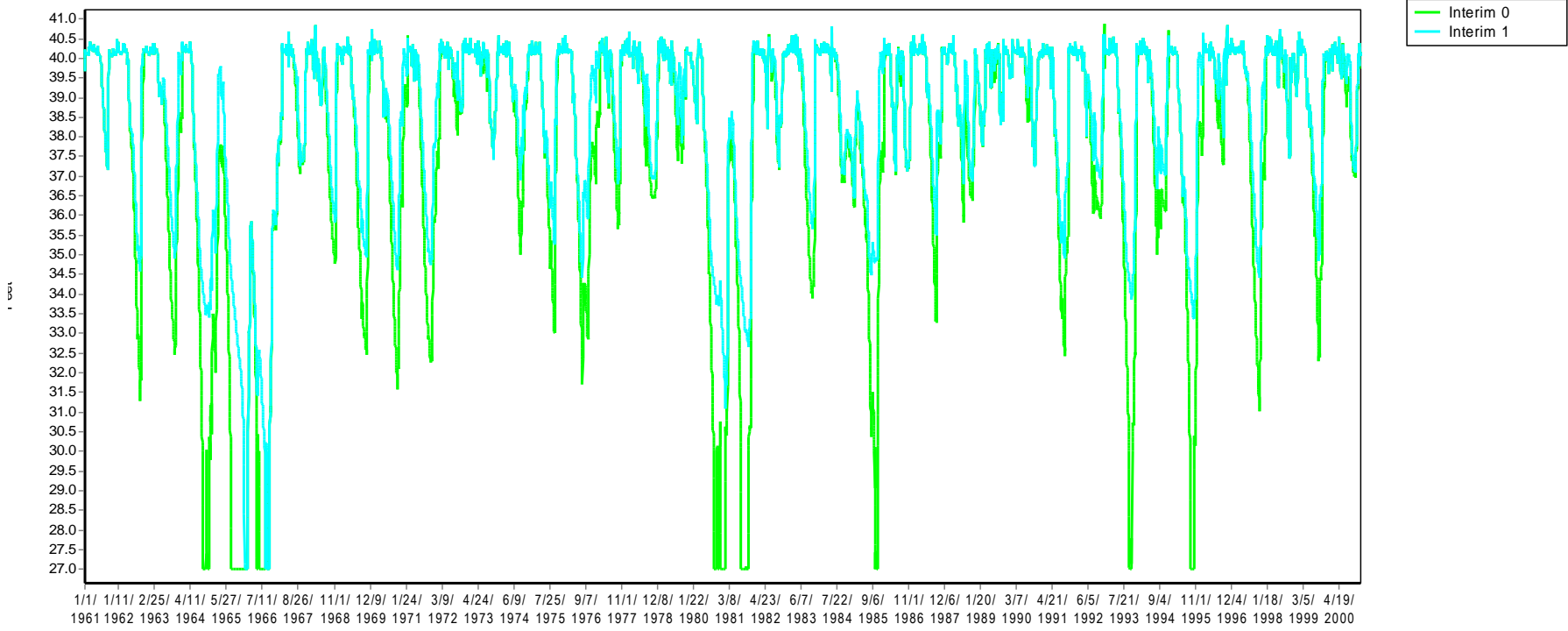
Table A.2 Summary of Interim Operational Plan Scenario Results

A.3 Reservoir Storage Elevation Graphs

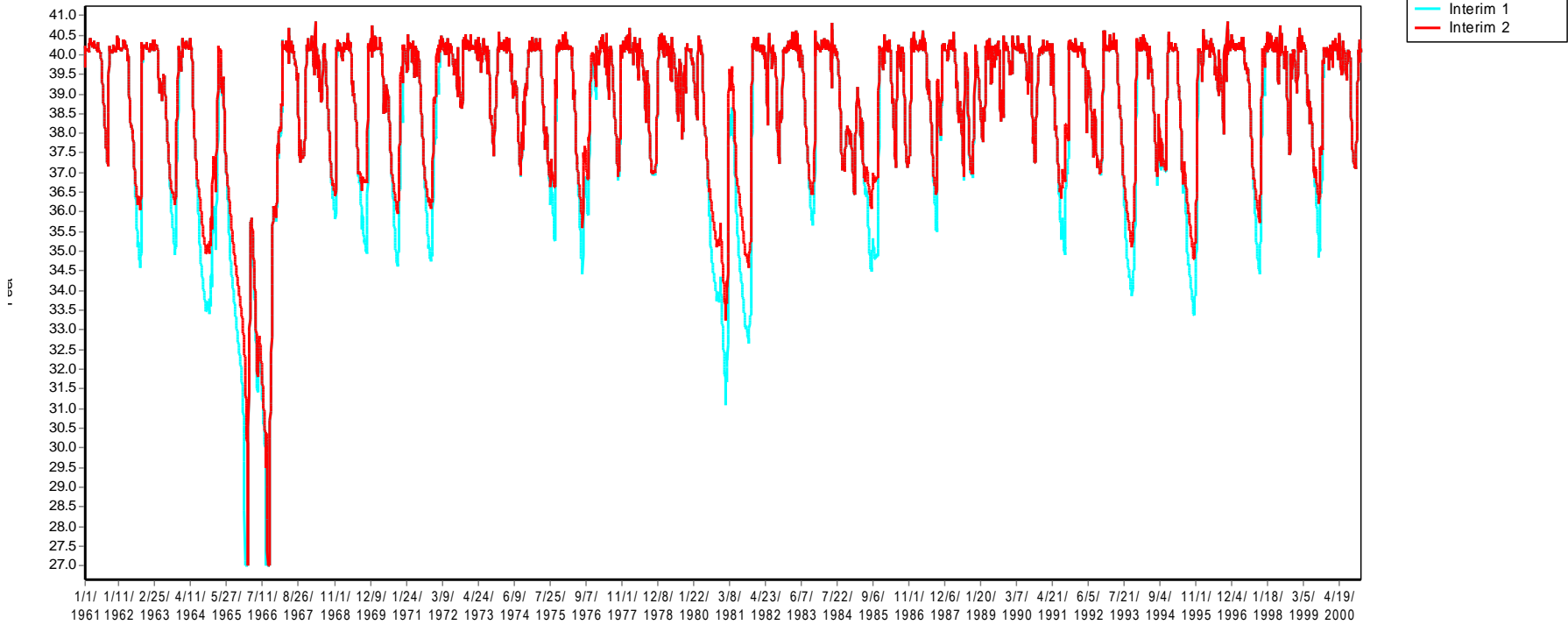
The Reservoir storage elevation graphs below depict the water level in the Reservoir over the model period from 1962–2000 under each scenario's conditions. For reference, the spillway of the Reservoir is modeled at 40 ft elevation and the water intake pipe is located at 27 ft elevation.



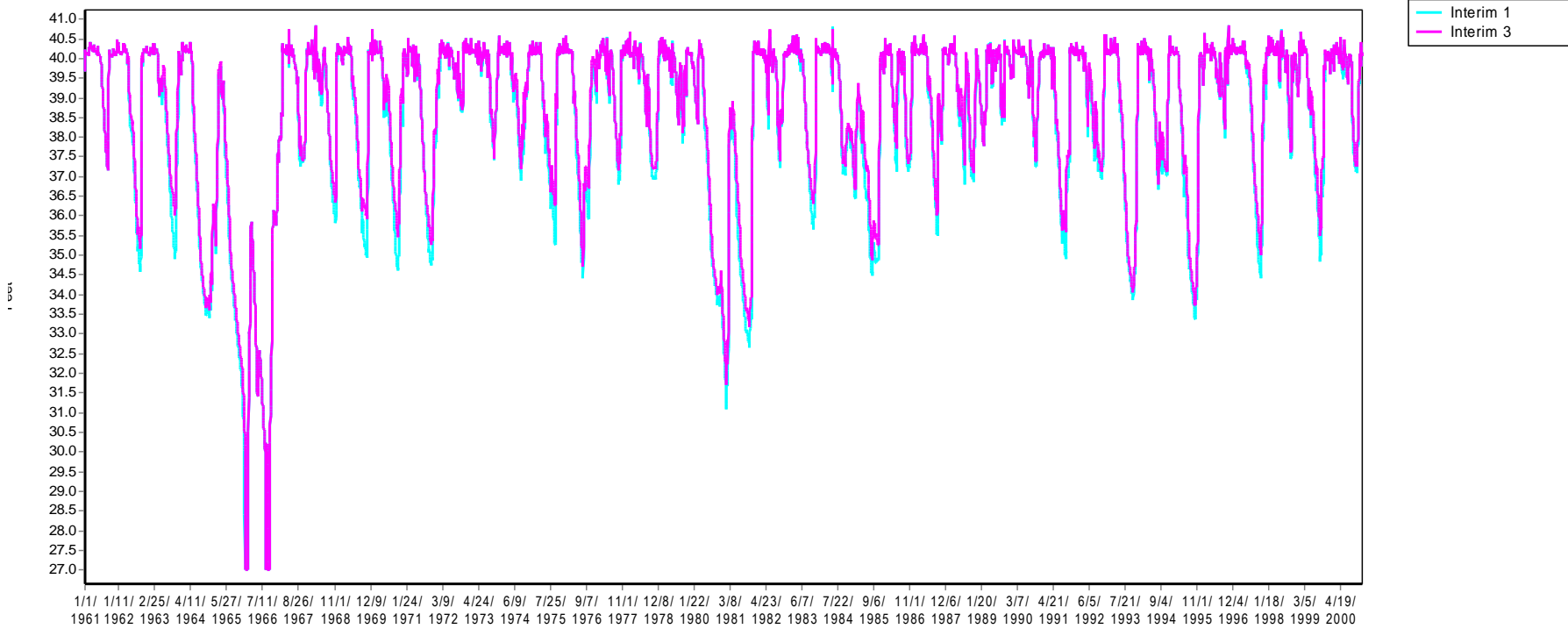
Reservoir Storage Elevation
Reservoir: The Reservoir, All days (366)



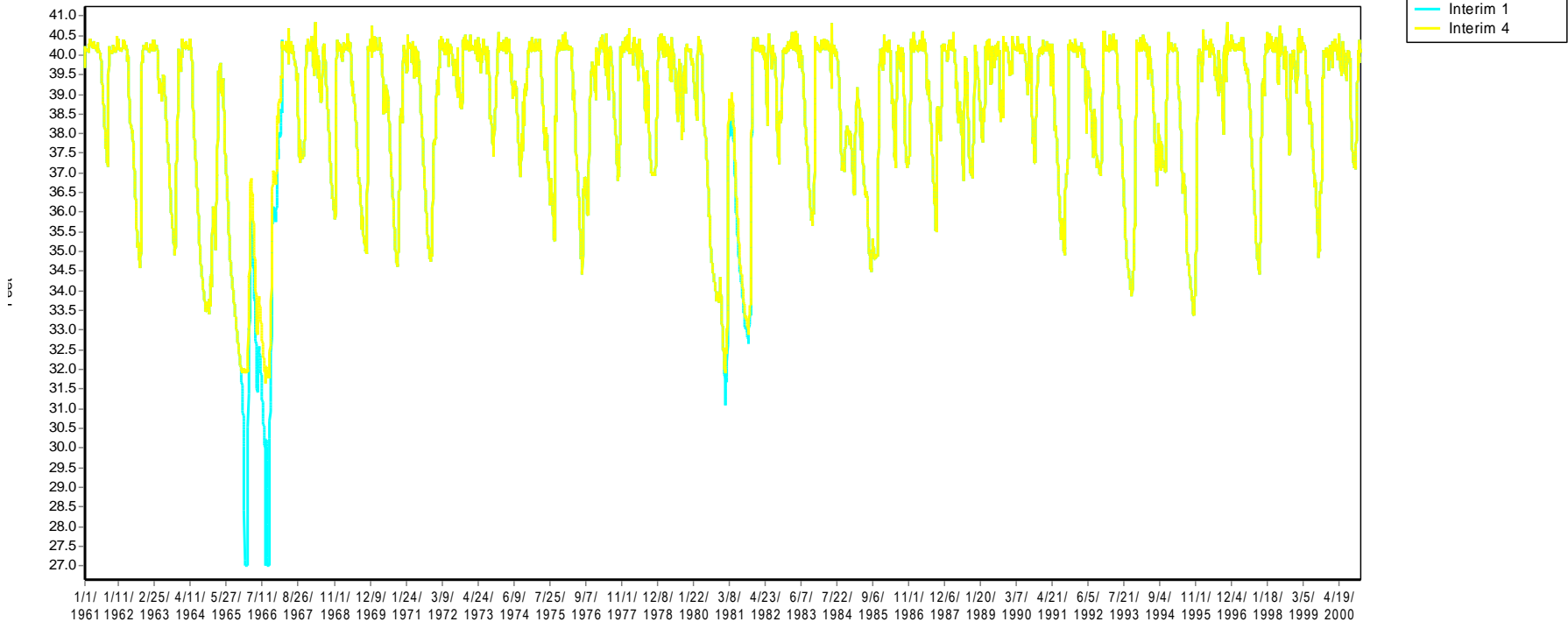
Reservoir Storage Elevation
Reservoir: The Reservoir, All days (366)



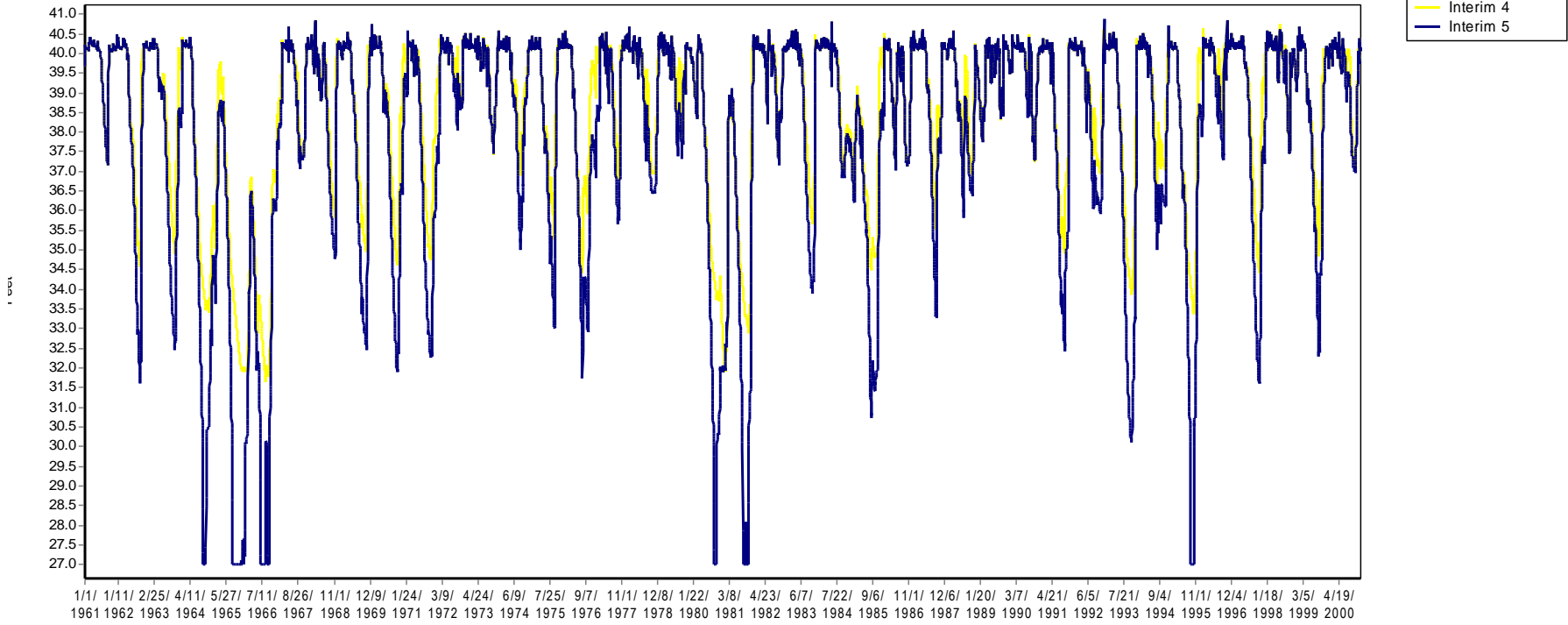
Reservoir Storage Elevation
Reservoir: The Reservoir, All days (366)



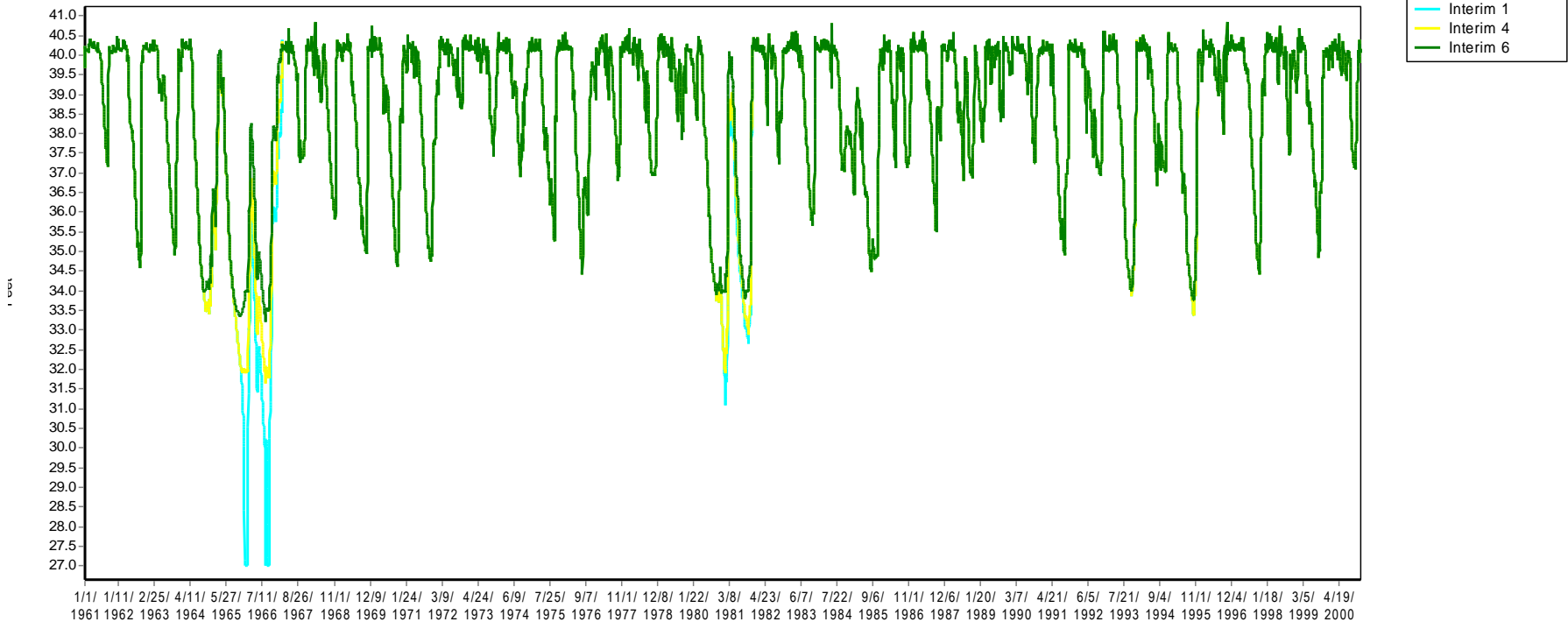
Reservoir Storage Elevation
Reservoir: The Reservoir, All days (366)



Reservoir Storage Elevation
Reservoir: The Reservoir, All days (366)



Reservoir Storage Elevation
Reservoir: The Reservoir, All days (366)



A.4 Water Supply Delivered

The amount of water needed by the Town varied with the length of irrigation restriction and duration of total outdoor water bans. With no demand management (“Interim -1”), maximum summer water use was about 2.4 mgd and annual demand was 543 million gallons. Under the current irrigation restriction and total water ban assumptions (“Interim 4”) the maximum summer water use is about 2.0 mgd and annual demand is 491 million gallons. Increased demand for water begins in mid-April and continues through mid-October. The “Interim 3” scenario shows water demand if the irrigation restriction season is expanded from May 1 - September 30. The maximum water use is still about 2.0 mgd, but total annual demand is reduced to 475 million gallons.

