Lake Delhi Dam - Draft Operations Plan
May 23, 2014

1. Introduction

Lake Delhi Dam is located on the Maquoketa River in Delaware County, Iowa. The dam is maintained and managed by the Lake Delhi Combined Recreational Facility and Water Quality District (District). Normal observation, recordkeeping, routine inspection, and maintenance are the responsibilities of the District and designated dam operators.

Lake Delhi Dam will be reconstructed in 2014. Detailed descriptions of reconstruction planning, analysis, and design can be found in the *Lake Delhi Dam Reconstruction Supporting Design Report*.

This Operation Plan (Plan) is to be used in conjunction with the comprehensive *Roller Gate Operation and Maintenance Manual* supplied by the gate manufacturer, Linita Design and Manufacturing Corporation. From now until the end of gate system commissioning, this draft Plan should be considered a working document as it is anticipated that revisions and supplements will come about as a result of construction, final control equipment configuration and programming, commissioning, and resource agency consultation. Once finalized per gate installation and commissioning this Plan should continue to be reviewed periodically and revised to reflect actual maintenance and operation of the reconstructed dam.

2. Dam Description

Lake Delhi Dam was constructed in 1922 for the purpose of generating hydroelectric power. Power generation ceased in 1973. Ownership of the dam was ultimately obtained by the Lake Delhi Recreation Association, who maintained the lake for recreational purposes. In July 2010 a large flood breached and eroded away the dam's southern embankment. Reconstruction of Lake Delhi Dam and restoration of the lake began in 2014. The project included repair of several existing features and construction of a new southern embankment and spillway.

Major components of Lake Delhi Dam include the north embankment, powerhouse, gated spillway structure, labyrinth weir spillway, and south embankment.

The north embankment is located between the north river bank of the Maquoketa River consists of vertical concrete retaining walls separated by approximately 25 feet of earthen fill. 230th Avenue ends at the dam and the pavement surface forms the top of dam. The concrete retaining walls were constructed as part of the 2014 reconstruction project and are connected to the powerhouse structure.

The powerhouse structure was built in the 1920s by Interstate Power. Power generation ceased in 1973. The powerhouse is a multi-level reinforced concrete structure consisting of three main rooms on three levels. The upper level is the control room, the middle level is the turbine room, and the lower level is the mechanical room. The roof of the powerhouse is a concrete bridge deck with an operator platform separated from the bridge deck by a concrete barrier on the upstream side. Two turbine intakes with a trash rake system are located on the upstream side of the structure. Flow through these intakes is controlled by the wicket gates which were used to discharge normal flows at the dam prior to the 2010 breach. Hydro intakes intakes are no longer used for passing discharge.

The gated spillway structure is located adjacent to the powerhouse structure and includes three concrete ogeee spillways separated by concrete spillway piers and abutment walls, with a concrete bridge deck over the top. The 2014 reconstruction project included resurfacing and repair of the concrete spillway and pier/abutment walls. Flow through the 25 foot wide by 20 foot high spillway openings are controlled by vertical steel roller gates and associated hoisting equipment and control systems which were installed during the 2014 reconstruction project. The crest of the ogee spillway is at elevation 879.8 ft (project datum NAVD 88), approximately 16.5 feet below the normal pool elevation. The roller gates will normally be kept closed and only opened to assist in passing high flows at the dam.

A concrete labyrinth weir spillway structure connects to the south end of the gated spillway structure. The labyrinth weir structure is 188-foot long and contains 540 feet of actual weir length. The weir is an approximately 12-foot tall concrete wall extending across a concrete slab foundation. The concrete slab foundation sits on an earthen embankment. The earthen embankment and spillway structure were installed during the reconstruction project. The crest of the labyrinth weir is set to maintain the normal pool elevation. Below the labyrinth weir and set on the downstream slope of the earthen embankment is a 3h:1v concrete chute and a USBR Type III stilling basin.

The south embankment area consists of an earthen embankment with a sheet pile cutoff installed on the upstream side of the paved road/access area on top of the embankment. This area provides gate controlled access to parking and a maintenance path that parallels the concrete training wall on the downstream side of the south embankment.

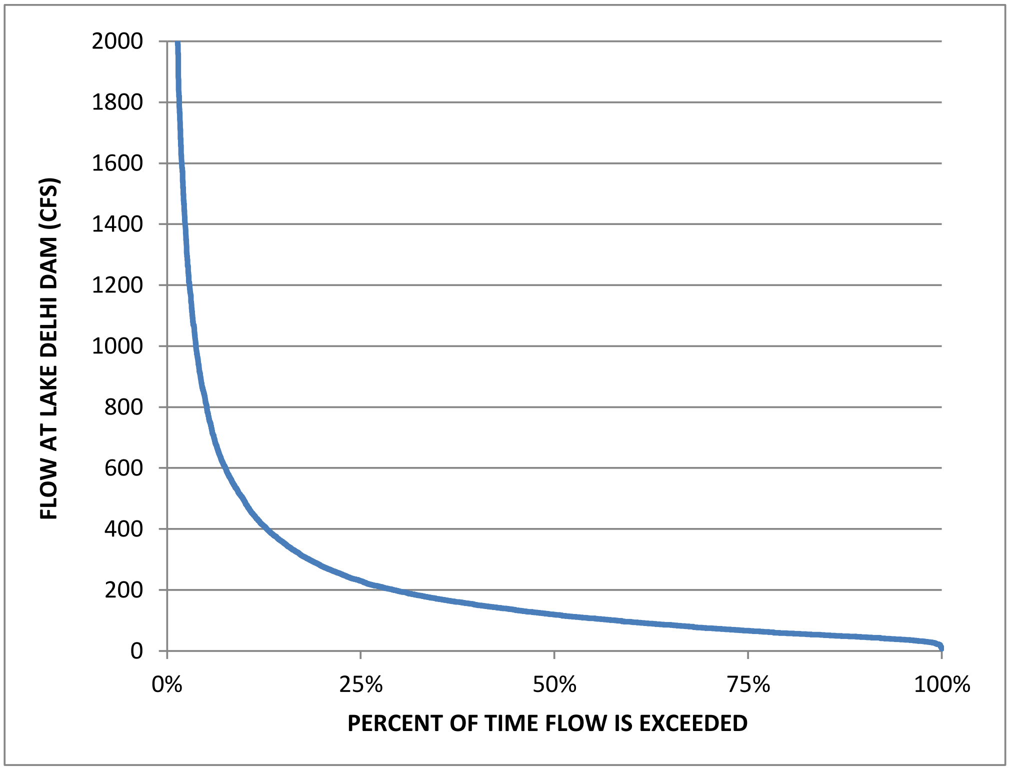
3. Maquoketa River Flows

U.S. Geological Survey (USGS) maintains a river flow gage near Manchester, Iowa at the Highway 20 crossing roughly 12 miles upstream of Lake Delhi Dam. The tributary drainage areas for the Maquoketa River at Highway 20 and at Lake Delhi Dam are 300 square miles and 349 square miles respectively. USGS performed a frequency analysis of gage flows which were adjusted by USGS regional drainage area ratio methodology to estimate return period flows at Lake Delhi Dam. Table 3-1 provides the return period flows for the USGS gage and Lake Delhi Dam.

Table 3-1 Return Period Flows

Return Period (yrs)	Annual Exceedance Probability	USGS Gage Flow (cfs)	Lake Delhi Dam Flow (cfs)
1	0.95	1,400	1,500
2	0.5	4,500	4,800
5	0.2	8,600	9,200
10	0.1	12,300	13,200
25	0.04	18,130	19,400
50	0.02	23,400	25,100
100	0.01	29,600	31,700
200	0.005	36,800	39,400
500	0.002	48,200	51,500

A flow duration curve provides a characterization of the range of flows that are likely to occur at the dam. Figure 3-1 provides the flow duration curve for Lake Delhi Dam which was developed using USGS daily gage flows.



Lake Delhi Dam Flow Duration Curve
Figure 3-1

Average daily flows at Lake Delhi Dam are in the range of 150 cubic feet per second (cfs).

4. Spillways

Lake Delhi Dam uses both the labyrinth weir spillway and spillway gates to maintain the normal pool elevation. During most Maquoketa River flow conditions, the labyrinth weir spillway will be the sole spillway in operation. The spillway gate system will be used during high river flow conditions to help maintain the lake's normal pool elevation over a wider range of flows and to safely pass large volume flood flows.

4.1 Labyrinth Weir Spillway

The labyrinth weir crest is set to maintain a normal pool elevation of 896.3 ft during typical flow conditions. The crest elevation varies between 895.9 at the downstream apexes of the labyrinth up to 896.4 ft at the upstream apexes of the labyrinth. This configuration allows the discharge to be more concentrated at the downstream end of the spillway during low flows and maintain the pool closer to 896.3 ft over a wider range of flows. This adjustment does not impact the overall hydraulic capacity of the weir for passing flood flows.

The labyrinth weir can maintain the pool within 0.3 feet (i.e. 4 inches) of normal pool for flows ranging from 10 cfs to 480 cfs, which is roughly 85% of the time. When flows increase to a level where the pool starts rising more than 0.3 feet above normal (896.6 ft) the spillway gates will begin to open to maintain the normal pool elevation of 896.5 ft.

The labyrinth weir is a fixed crest weir so no operation will be required. A 6-foot by 6-foot stoplog gate is located at the north end of the labyrinth weir. A steel grate operator platform is provided off of the top of the buttress wall and stoplogs will be raised and lowered using a jib crane mounted to the buttress wall. The crest (i.e. top of stopologs) will be at the normal pool elevation of 896.3 feet-msl. Stoplogs will be removed to sluice floating debris from the pool to downstream or to maintain run-of-river flows during times of extreme low flows.

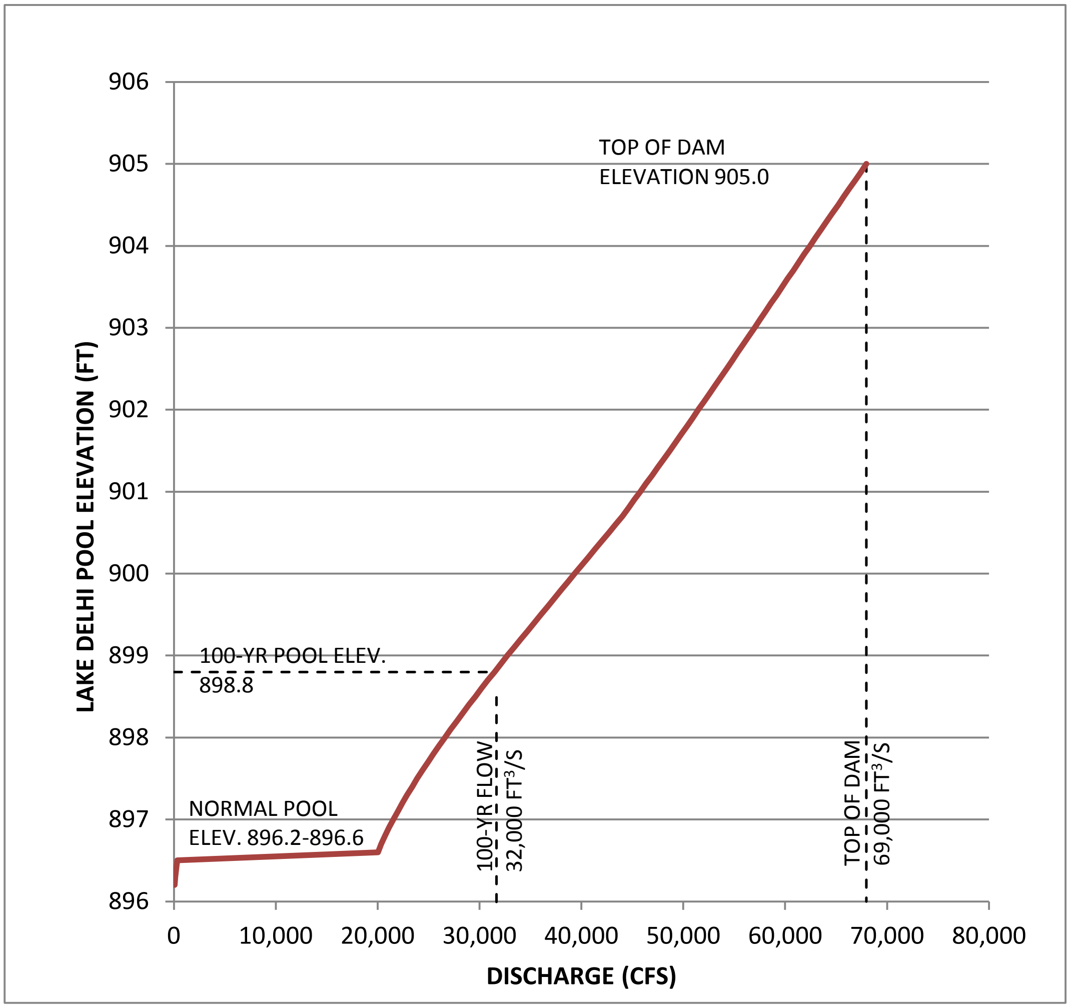
4.2 Spillway Gate System

The three vertical steel roller gates are operated by three electric motor driven screw actuators. The three gate openings are approximately 25 feet wide by 20 feet high with a crest elevation of 879.8. Two submersible level transducers will be mounted to the powerhouse on the pool side of the dam to monitor pool elevation. The level transducers will be linked to automatic control of the gates. Manual control of the gates will be available at the control panel in the electrical room and at the gate actuators.

Gates will be set to open sequentially based on specific pool levels. The first gate will open when the pool elevation exceeds 896.6 ft. The gate will open in small increments, adjusting to maintain a pool elevation of 896.5 ft. In most cases, a single gate will be sufficient to pass the higher flow and maintain a constant pool elevation of 896.5 ft. During flood magnitude events all three gates will be used and will open in combination so flood discharge is spread more evenly between gate bays. The gate which opens initially will also switch between opening events, so one gate is not overused. The pool elevation of 896.5 ft can be maintained up to flows of approximately 19,700 cfs which corresponds to approximately the 25-year flood.

4.3 Discharge Capacity

The Lake Delhi Dam will discharge flow using the labyrinth weir spillway to provide pool level control and the spillway gates to pass high magnitude flow events. Figure 4-1 provides a graph of the dam's stage-discharge curve.



Lake Delhi Dam Stage-Discharge Curve
Figure 4-1

The normal pool range can be maintained up to flows of approximately 19,700 cfs which corresponds to the 25-year flood. Above 19,700 cfs, spillway gates are open above pool level and the pool level increases with flows. The dam can discharge the 100-year flood with roughly a 2 foot increase above normal pool. Table 4-1 provides a summary of return period flows and corresponding pool levels at Lake Delhi Dam.

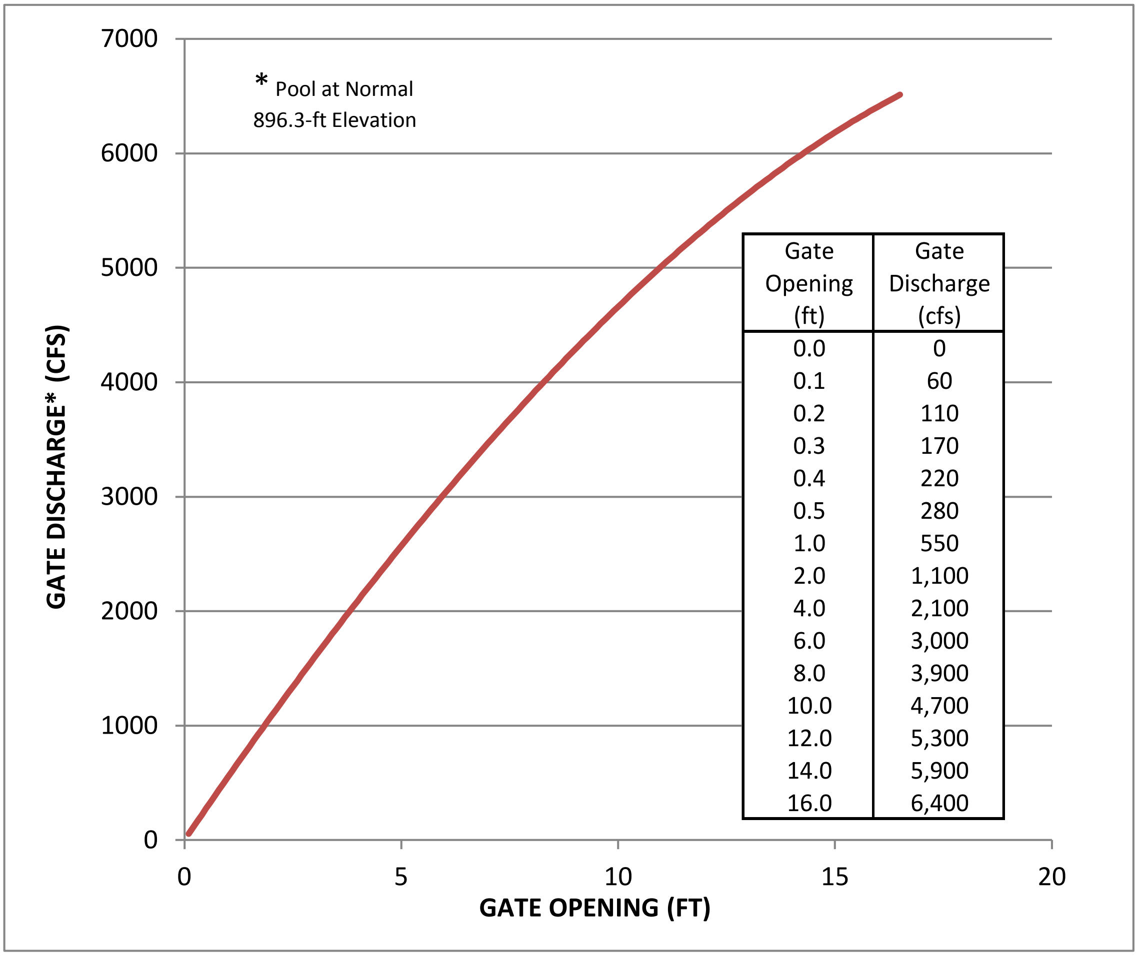
Table 4-1 Lake Delhi Dam Pool Elevations

Return Period (yrs)	River Flow (cfs)	Pool Elevation (ft)
2	4,900	896.5
5	9,400	896.5
10	13,200	896.5
25	19,400	896.5
50	25,100	897.7
100	31,700	898.8
500	51,500	901.9

* River flows based on USGS Bulletin 17B Analysis of Maquoketa River.

** Pool elevations based on Excel/HEC-RAS model by Stanley Consultants.

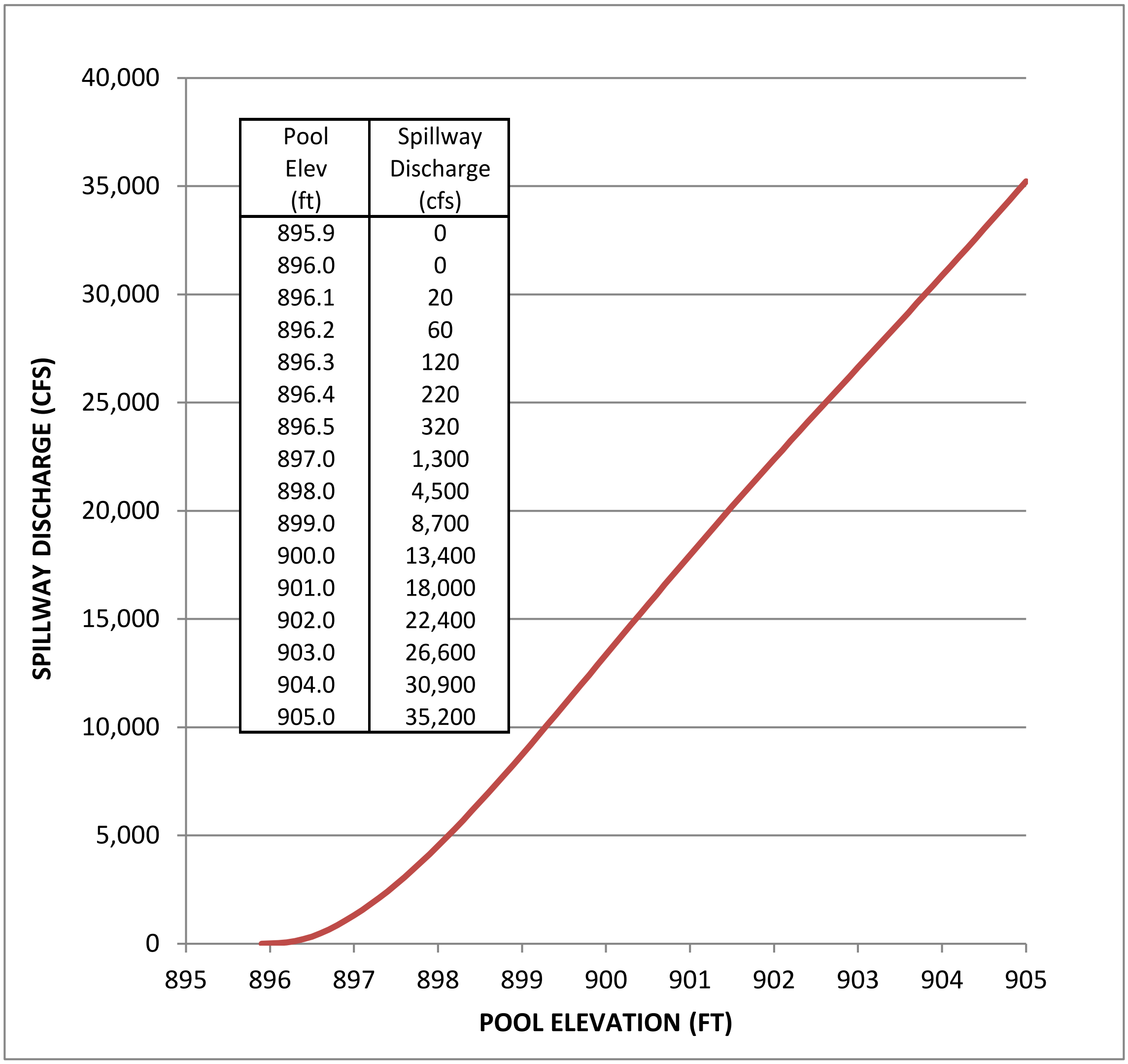
The majority of gate operation will occur during smaller high flow events. One of the gates will open a few inches to a few feet to help maintain normal pool. The spillway gates open from the bottom and have a crest elevation of 879.8 ft, approximately 16.5 below the normal pool. Because of their depth, the gates can discharge a relatively large volume of water with a small gate opening. Figure 4-2 provides the discharge curve for a single gate operating at normal pool. The gate opening procedure is described in more detail in Section 6.



Gate Opening (ft)	Gate Discharge (cfs)
0.0	0
0.1	60
0.2	110
0.3	170
0.4	220
0.5	280
1.0	550
2.0	1,100
4.0	2,100
6.0	3,000
8.0	3,900
10.0	4,700
12.0	5,300
14.0	5,900
16.0	6,400

Gate Discharge Curve
Figure 4-2

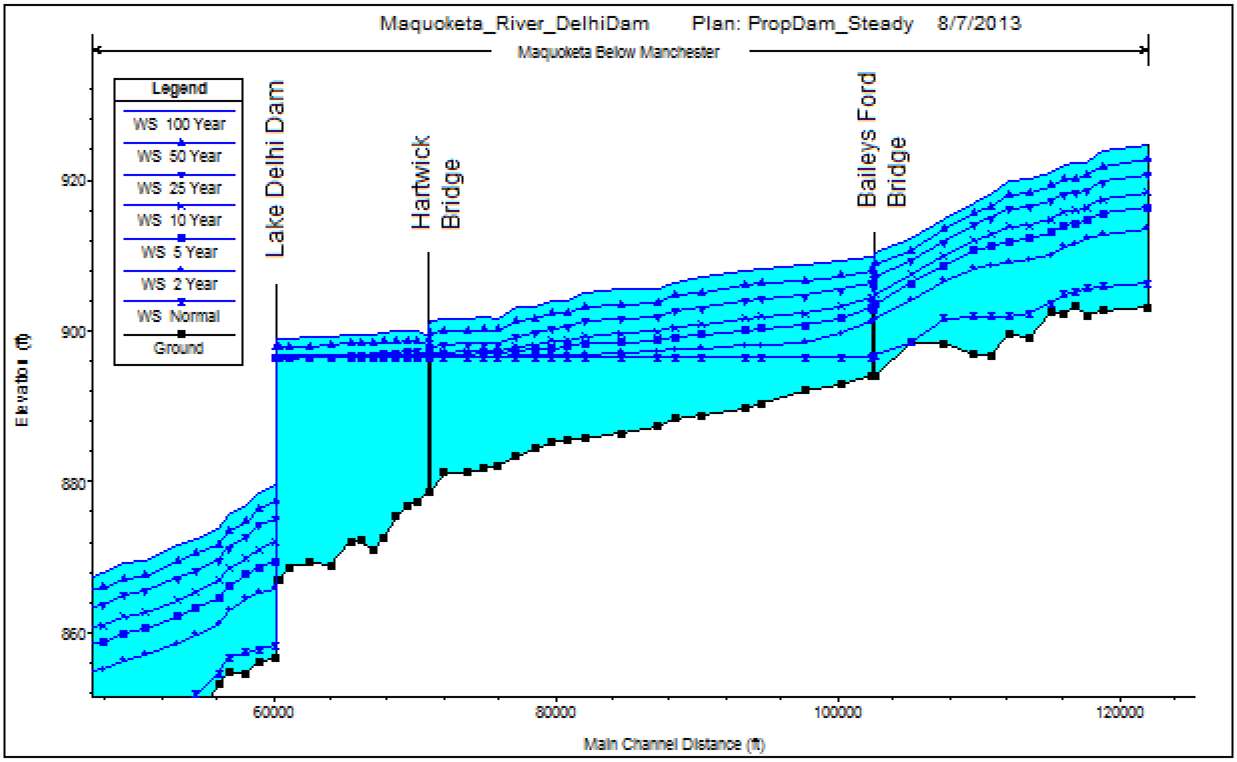
During river flow conditions below 480 cfs, the labyrinth weir spillway will maintain the normal pool. The labyrinth weir spillway provides the majority of discharge capacity during low to normal flow conditions. Gates provide the majority of discharge capacity during flow conditions up to approximately 20,000 cfs (i.e. 25-year event). As flows increase further and the pool rises above normal, the labyrinth weir provides additional discharge capacity as the depth of water over the weir increases. Figure 4-3 provides the labyrinth weir discharge curve.



Pool Elev (ft)	Spillway Discharge (cfs)
895.9	0
896.0	0
896.1	20
896.2	60
896.3	120
896.4	220
896.5	320
897.0	1,300
898.0	4,500
899.0	8,700
900.0	13,400
901.0	18,000
902.0	22,400
903.0	26,600
904.0	30,900
905.0	35,200

Labyrinth Spillway Discharge Curve
Figure 4-3

The labyrinth spillway and gates maintain the pool elevation at the dam. The ability of the spillways to control the pool elevation upstream of the dam (i.e. lake level in upstream segments of lake) diminishes as flow levels exceed 3000 cfs. During flood magnitude events, the hydraulic capacity of upstream bridges and the river channel control the water elevation. This is demonstrated in Figure 4-4, which provides a profile plot of the HEC-RAS model upstream of the reconstructed Lake Delhi Dam for normal flow (200 cfs) to 100-year flood conditions (32,000 cfs).



Lake Delhi Dam HEC-RAS Profile
Figure 4-4

During normal flow conditions, the pool elevation of 896.3 can be maintained upstream to the Baileys Ford Bridge. However, as flows increase the length of the flat pool is reduced. During the 2-year flood it extends to a point 3.5 miles upstream of Lake Delhi Dam. By the 5-year flood it is approximately at Hartwick Bridge. The dam can maintain the normal pool elevation up to roughly the 25-year flood, however on the downstream side of Hartwick Bridge it is approximately 1 foot higher (i.e. 897.3 feet) than the normal pool, upstream of Hartwick Bridge it is 1.5 feet higher than normal pool, and at Baileys Ford Bridge it is approximately 10 feet higher than normal pool. This trend is maintained as flows increase.

Flows released and the pool elevation maintained at the dam will be solely based on the pool level transducers located at the dam.

5 Public Access and Safety

The following measures have or will be implemented to enhance public safety with respect to the dam:

- Chain link fencing is located at and around the dam abutments to impede unauthorized access to the powerhouse/spillway structure and the labyrinth spillway and downstream training walls.
- A steel safety cable with buoys is located across the Maquoketa River, just upstream of the dam.
- Additional access control to the operator platform is provided by a locked gate.
- Prior to making significant changes to spillway gates, operators will visually verify that no persons are located in areas that will experience sudden changes in water discharge or elevation.
- LED spotlights yoke mounted on railings to provide situation spotlights to light up the buoy barrier system and spillway area.

6 Operating Objectives and Procedures

The primary objectives for dam operation are to:

- Maintain pool elevation within normal range for river flows up to 19,700 cfs.
- Maintain a run-of-river discharge (i.e. inflow = outflow) during most flow conditions.
- Minimize the upstream flood levels during high river flow events.
- Maintain a downstream flow of approximately 83 CFS as required by Iowa Administrative Code 567-52.3(455B) and designated in Iowa Administrative Code 567- 52.8(455B during pool filling (i.e. when run-of-river not being maintained).

Additional requirements are listed in the DNR Permit issued in 2014. A copy of the DNR permit is included as Attachment A. A summary of permit conditions include the following: TBD

6.2 Operating Procedures

Operating procedures are established to meet primary operating objectives, provide safe facility management and satisfy DNR permit requirements. The reconstructed dam will require no mechanical operation for Maquoketa River flows up to 480 cfs. The labyrinth spillway will be a surface discharge (not below surface as under pre-breach condition). Gates will open automatically when the lake level exceeds 896.6 ft and will adjust to maintain a pool elevation of 896.5 ft.

Pool levels are monitored by a submerged pressure transducer located on the face of the retaining wall on the upstream side of the powerhouse. A programmable logic controller (PLC) located in the Operator Room of the powerhouse constantly reads pool levels and gate position. The system will and raise or lower gates as required to maintain the desired, pre-set pool level during higher flow conditions.

Automatic operation can at any time be overridden by manual operation (only available at the dam) should the need arise. A data connection to the PLC will be installed to allow for remote monitoring of the dam and alarm reporting in the event of a system alarm.

The gate operation logic is established to balance the gates dual objectives of maintenance of run-of-river flow and normal pool with safely passing flood flows. Maintaining run-of-river flow and normal pool requires small adjustments to gate openings. Passing large magnitude flood flows requires rapid opening and closing of gates. The gate operation logic includes three phases with varying opening increments to provide the range of gate function required to meet the various operating objectives. Table 6-1 provides a summary of the gate opening phases.

Table 6-1 Gate Opening Phases

Gate Opening Phases			Opening Increment (ft) *					
			Gate 1		Gate 2		Gate 3	
Phase	Start (ft)	End (ft)	Open	Close	Open	Close	Open	Close
1	0	2	0.1	0.1	0.1	0.1	0.5	0.5
2	2	10	0.2	0.2	0.5	0.5	1	2
3	10	20	0.5	0.5	1	2	1	2

* Gates opening/closing rate is approximately 1 foot/minute

Gates will open incrementally so flows are not concentrated on a single spillway bay. Gate 1 will open to 2 feet, then Gate 2 will open to 2 feet, then Gate 3 will open to 2 feet. Gate 1 will then open to 10 feet and so on. The gate opening order will adjust following each opening event. Once gates fully close, the designated opening order will shift down one gate, so Gate 2 becomes Gate 1, Gate 3 becomes Gate 2, and Gate 1 becomes Gate 3. This will also help distribute flows more evenly among the three gates and spillway bays.

The PLC will constantly monitor pool levels and gate position but will not constantly adjust gates. Gates will be adjusted on a periodic basis. Every 5 minutes the PLC will use the pool level reading and gate level reading to adjust gates open or closed one increment. If all gates are closed, then the PLC makes no gate adjustment until the pool level reaches elevation 896.6 feet. Then Gate 1 will open by 0.1 feet every 5 minutes until the pool level reaches elevation 896.5 feet. If it is a significant high flow event, multiple gates will open according to the phasing and increments in Table 6-1. If the pool drops below 896.5 feet the gate(s) begin closing by their specific increments on the 5 minute frequency. Gates will not operate concurrently unless the PLC system is overridden by manual control.

This phasing is programmed into the PLC. The 5 minute frequency is a balance between providing sufficient time to:

- Allow the pool elevation to adjust to the gate opening or closing.
- Allow gates to adequately respond to a flood condition.

Phase 1 will handle over 99% of the flow conditions historically experienced at Lake Delhi Dam. In this phase gates open in very small increments to allow minor adjustments for the smaller magnitude (i.e. less than 3000 cfs) high flow events that will comprise the majority of gate openings. Phases 2 and 3 involve larger opening increments to provide the gates a more rapid response to quickly rising flows that accompany a flood condition. Note that Phases 2 and 3 include closing rates that are faster than opening rates because flood flows typically decrease at a faster rate than they increase.

The construction contract includes initial programming of the PLC as well as a subsequent PLC programming session sometime within the first year of operation to refine operating parameters.

Table 6-1 presents the operating procedure to be implemented by the District, including the procedure for high river flow events. This operating procedure will be reviewed periodically and adjusted if needed. The operating procedure is further described as follows:

- Normally, due to the fixed, overtopping labyrinth spillway the dam will be in run-of-river mode and will maintain the range of normal pool elevation between 896.2 and 896.6 feet.
- For river flows up to approximately 480 cfs, river flow will spill over the fixed labyrinth spillway. The pool elevation will fluctuate between elevation 896.2 and 896.6 feet.
- For river flows greater than 480 cfs, the roller gates will begin to open automatically when the pool elevation exceeds 896.6 feet. The submersible level transducer will be used to read the pool elevation so it will not be impacted by wave action.
- The PLC will be programmed to maintain a pool elevation of 896.5 feet when gates are open. The PLC will constantly monitor the pool level. Every 5 minutes the PLC will use the pool elevation to determine whether to open or close the gate by one increment. The gate will be raised if the pool is above 896.5 feet and the gate will be lowered if the pool is below 896.5 feet.
- When river flows approach the approximate 25-year flood event (19,700 cfs), the "normal pool" capacity of the labyrinth weir spillway and spillway gates will be reached. The pool elevation will be at approximately 896.5 and gates will be open to slightly above the pool elevation.
- As flows exceed 19,700 cfs, the gates will open fully and the river flow will control the pool elevation. The 100-year flood event (~32,000 cfs) can be passed with a pool elevation at the dam of approximately 898.8 feet. The spillway design flood of approximately 70,000 cfs is passed with a pool elevation at the dam of approximately 904.9. Note, that the river levels upstream of the dam are not a "flat pool" during flood magnitude events.
- As flow levels decrease following a high flow event, gates will lower to continue maintaining a pool elevation of 896.5. Once gates fully close, they will not open again until the pool reaches 896.6.
- If the lake level ever drops below 896.0 during extended periods of low river flows, the stoplog gate will be used to pass the run-of-river flow.

Table 6-1 Lake Delhi Dam Preliminary Operation Plan

	Duration/Frequency			Labyrinth Weir	Spillway Gate					
River Discharge (cfs)	Annual Duration (%)	Return Period (yrs)	Pool Elevation (ft)	Discharge (cfs)	Gate 1 Opening (ft)	Gate 2 Opening (ft)	Gate 3 Opening (ft)	Gate Discharge (cfs)	Total Discharge (cfs)	Comment
5	99.9	--	896.0	5	0	0	0	0	5	Use stoplog gate if pool drops below 896.0
60	93	--	896.2	60	0	0	0	0	60	
120	65	--	896.3	120	0	0	0	0	120	
480	17	--	896.6	480	0	0	0	0	480	Maximum flow prior to gate operation
1000	6	--	896.5	320	1.2	0	0	680	1000	--------------------------
3000	1	--	896.5	320	2.0	2.0	0.3	2680	3000	
4900	--	2	896.5	320	4.8	2	2	4680	5000	Gates operating to maintain normal pool
9400	--	5	896.5	320	10	6.5	2	9080	9400	
13,200	--	10	896.5	320	10	10	7	12,880	13,200	------------------------
19,700	--	25	896.5	320	20	20	20	19,380	19,700	Highest flow where gates can maintain normal pool
25,100	--	50	897.7	3,400	20	20	20	21,700	25,100	50-year flood
31,700	--	100	898.8	8,300	20	20	20	23,400	31,700	100-year flood
51,500	--	500	901.9	22,000	20	20	20	29,500	51,500	500-year flood

6.3 Operating Personnel

The District has formed a Dam Operating Committee which is assembling a staff of dam operators for Lake Delhi Dam. The list of staff and organization chart and schedule will be provided to the DNR in a subsequent version of this manual.

Operating staff will be on call 24 hours per day, 7 days per week. Operator staff duties will be focused on observation and maintenance. Most flow conditions will be handled by the labyrinth weir. During higher flow conditions, the gates will raise automatically to maintain an established normal pool level. Protocol for operator staff observation is provided by the following:

- Staff is on call 24 hours per day, 7 days per week.
- When flows are below 480 cfs (i.e. no gates operating)
  - Staff visits dam once per day.
  - Pool levels and river flows are checked remotely every two hours during working hours.
- When flows are above 480 cfs and below 3000 cfs (gates begin operating)
  - Staff visits dam once every 4 hours during daylight hours.
  - Pool levels are checked remotely every two hours during working hours.
- When flows are above 3000 cfs (high flow or flood event coming through)
  - Staff is onsite during daylight hours.
- When flows exceed 13,200 cfs (10-year flood or greater)
  - Staff is onsite all hours.

The new spillway gate control system will include a remote VPN device to allow off-site access to the control system for remote monitoring of the system. The remote VPN device will also allow for remote maintenance of the control system and minimal remote operation (such as alarm acknowledgement) of the control system. Note that manual gate control will not be possible using the VPN device. Available real-time data will include pool level and spillway gate positions. Alarms will indicate high pool level, low pool level, gate opening, power failure, and PLC failure. As a backup to remote monitoring and onsite staff, the operating system will provide offsite notification to operating staff, management, and public safety agencies if alarms are triggered.

Operation of the new spillway gate system will be the responsibility of the operating staff. Detailed operation and maintenance manuals for specific equipment such as gates and control systems were developed by the manufacturers during the procurement process and included as part of the operation and maintenance process. Operators will be trained using this manual and other operation/maintenance documentation.

6.4 Monitoring and Flood Response

Operating protocol at the reconstructed Lake Delhi Dam will include automated and observational monitoring of lake levels as well as comparing dam discharge rates to inflow rates translated from the USGS gage in Manchester (#05416900). Operators will also monitor weather conditions and forecasts to anticipate potential changes in flow conditions.

During times of anticipated or actual significant flooding or potentially hazardous conditions, operating staff should also check the Lake Delhi Dam Emergency Action Plan. This plan includes requirements for step-by-step actions for a series of flood and emergency scenarios.

6.5 Discharge Measurement

Transducer and control equipment will monitor upstream pool levels and gate position (i.e. gate opening). Discharge from the dam will be computed using established engineering equations and the reported "head" over the labyrinth spillway and gate openings.

6.6 Communication

Operating staff should notify the Iowa Department of Natural Resources Dam Safety Engineer (Jon Garton: 515.281.6940) of any deviations from normal pool operating activities. Examples of activities that warrant notification include unusually high or low water levels, operation changes, non-routine maintenance activities, and construction activities

7. Monitoring and Inspection Procedures

7.1. General

A sound inspection program is an integral part of the operation and maintenance of a dam. An inspection program is intended to identify deficiencies and unsafe conditions, and the maintenance required to preserve the integrity of the structure to protect life, health, and property. The Lake Delhi Dam inspection program includes provisions for routine and detailed inspections. This document includes forms that are to be used to perform and document inspections and maintenance.

7.2. Operating Staff Routine Inspection

This inspection is performed by dam operating staff as part of the normal surveillance, operation and maintenance of the dam. It includes but is not limited to frequent visual inspections of the dam's components. Record any and all maintenance and repairs performed on the dam and compile all repair reports into annual summary reports. Documentation of individual maintenance or repairs should take place at the time of the action and not wait for the annual routine inspection.

7.3. Annual Inspection

This inspection is to be performed by the District's representative and dam operating staff to assess the condition of structural, water retaining components, and operating equipment. The DNR Dam Safety Engineer should be invited to participate in the routine inspections. Inspections should take place annually or following major flood events. This inspection should provide a thorough, systematic evaluation of the dam and may require special equipment. Prior to performing inspections, inspectors should review past inspection reports, summary repair report for previous year, dam history, construction record plans and specifications. Inspections should include measurements, photographs, and sketches illustrating the condition of the structure.

The inspection should take place during low river flows such that roller gates are closed and the area immediately downstream of the gates can be viewed.

Inspection Form B-2 divides the dam into several components falling into six general areas. Inspection requirements for these components are provided below. A copy of the inspection report should be submitted to the DNR Dam Safety Program.

7.4. Public Safety

Inspect fencing and handrails for general condition, post/rail/mounting/connections, welds, fasteners, misalignment, and damage. Inspect signage for proper mounting and visibility. Inspect floating buoys for proper alignment, visibility and anchorage/support.

7.5. Dam Features

North Embankment

Inspect visible concrete components of the embankment walls for cracking, scaling, spalling, leaching, deterioration, settlement, misalignment, and joint protection. Check plumbness of vertical walls. Check pavement surface for loss of material, excessive cracking, edge deterioration, undermining, settlement, and potholing. Inspect storm sewer inlets for general condition, proper drainage, and for general condition of piping.

North Abutment and Downstream Area

Inspect massive block wall for visible signs of block shifting, material loss, and concrete block deterioration. Check earthen slope for signs of erosion or significant vegetation loss. Inspect storm sewer inlets for general condition, proper drainage, and for general condition of piping.

Verify presence of riprap on downstream end of stilling basin. Inspect stilling basin if gates have been used to pass flows exceeding 20,000 cfs for movement of concrete panels or areas of scour.

Powerhouse

Inspect visible structural concrete for new cracking, scaling, spalling, leaching, deterioration, settlement, and misalignment, and joint material loss. Check plumbness of vertical walls. Verify no flow is going through wicket gates and hydro openings. Inspect condition of pressure transducer conduit and cable connections. Verify that stilling well is not plugged or blocked and that the level transducer is conveying the water surface elevation to the PLC accurately. Check that staff gage is readable

Spillway and Gates

Inspect visible concrete for cracking, scaling, spalling, leaching, deterioration, settlement, misalignment, and joint protection. Check metal grating over gates and on stoplog operator platform for evidence of distress, misalignment and corrosion. Inspect gate operating mechanism for condition of paint and proper alignment. Inspect roller gate panels including steel components, welds, and connections. Inspect side and bottom seals for condition, leakage and proper alignment.

Additional inspection items will be provided following coordination with gate manufacturer.

Check pool area inside safety buoys for obstructions such as trees and debris.

Gate Control Features

Inspection items will be provided following coordination with gate manufacturer.

Labyrinth Weir and Spillway

Check pool area inside safety buoys for obstructions such as trees and debris. Inspect flow of water over weir during low flow condition. Verify that water is falling uniformly over "V" segments of weir. Inspect visible concrete of weir walls, training walls and spillway slabe for cracking, scaling, spalling, leaching, deterioration, settlement, misalignment, and joint protection. Check condition of riprap and articulated concrete block path above training wall. Inspect condition of riprap downstream of the stilling basin and check for areas of rock movement or scour.

South Embankment

South embankment should be observed for areas of seepage/piping, surface cracking, vegetation loss, unwanted vegetation, seepage-indicating vegetation, unintended trails, settlement, slumps, erosion/scour, and animal burrows. The riverbank and lake rim should be inspected for erosion/sour and riprap condition. Check pavement surface for loss of material, excessive cracking, edge deterioration, undermining, settlement, and potholing.

7.6. Monitoring Data

Staff Gage

Lake level can be observed from the staff gage located on the south powerhouse wall. The staff gage is viewable from the operator platform above the spillway gates. Gage measures pool elevation in feet. Gage digits match NAVD 88 elevation.

Soundings

Upstream soundings should be taken during the annual inspection. Downstream soundings can be taken with a level rod or similar instrument and it is not anticipated that a boat will be required. The downstream sounding program is limited to the river bottom immediately downstream of the spillway. Should soundings indicate presence of scour, a more formal and extensive sounding program will be required. Upstream soundings will require use of boat and depth-finding device. The upstream sounding program is intended to determine the depth of sediment immediately upstream of the dam only.

Streamflow Gage

The United States Geological Survey (USGS) maintains a streamflow gage (No. 05416900) on the Maquoketa River near Manchester, IA at Highway 20 (approximately 12 miles upstream of Lake Delhi Dam). Real time streamflow can be viewed on the internet at:

http://nwis.waterdata.usgs.gov/ia/nwis/uv/?site_no=05416900&agency_cd=USGS

The tributary drainage areas for the Maquoketa River at Highway 20 near Manchester and at Lake Delhi Dam are 300 square miles and 349 square miles respectively. River flows recorded at the USGS gage are typically going to be smaller than river flows at the dam. *Techniques for Estimating Flood-Frequency Discharges for Streams in Iowa* (USGS, 2001) provides regional empirical equations for translating flows between points on Iowa rivers that have proportional areas.

The multiplier for Manchester USGS gage flows to Lake Delhi Dam flows was computed to be 1.07. The river flow at Lake Delhi Dam can be approximated by adjusting the Manchester gage data by the ratio of drainage areas:

$$Q_{Delhi} = 1.07 \text{ x } Q_{Manchester}$$

Precipitation Data

The National Weather Service (NWS) provides weather monitoring, forecasts, and warnings for Iowa. Information can be viewed at:

http://www.nws.noaa.gov/view/states.php?state=IA

8. Maintenance Procedures

8.1 Structural Concrete

Minor repairs to structural concrete can often be made by operating personnel using products supplied by specialty manufacturers such as Sika Corporation.

8.2 Roller Gates

TBD

8.3 Gate Control Equipment

TBD

8.4 Embankment/Shoreline

Maintain shoreline in immediate vicinity of dam free of large vegetation. Immediately fill any discovered animal burrows. If problem persists attempt live trap and relocation of animal. Replace or supplement areas originally armored with riprap. Upon discovery of untended pedestrian trails, attempt to prevent further use of trail. Consult with specialty engineer if significant signs of distress are discovered including seepage/piping, surface cracking, settlement, and slumps.

9. Record Keeping

9.1. Posting

Maintain a master copy of this Operation and Maintenance Manual in the Control Room. Maintain additional up-to-date copies as shown on Table 6-1.

Table 6-1 - O&M Manual Distribution List

Organization	Contact Person
District	TBD
DNR – Dam Safety	Jon Garton

9.2 Training

Operation and maintenance training is to take place for designated personnel at the commencement of employment. Training should include complete review of this document.

9.3 Periodic Review

On a periodic basis (not to exceed five years) and if possible to coincide with the periodic inspection by Dam Safety Staff, the Operation and Maintenance Manual should be reviewed by operating personnel and DNR Dam Safety Staff and updated if necessary. Denote updated pages by changing the revision number and date found in the document footer. Provide revised pages to all persons on the distribution list of Table 6-1.

Certain statements and procedures listed in this Manual may be common to that of the Emergency Action Plan. Any revisions to the Emergency Action Plan should be considered for inclusion into the Operation and Maintenance Plan and vice versa.