February 20, 2012

VIA FEDERAL EXPRESS

Kimberly Bose, Secretary
Federal Energy Regulatory Commission
888 1st Street, NE, Room 1A
Washington, DC 20426

Chicopee River Projects: No. 10675, 10676, 10677, and 10678
Minimum Flow and Impoundment Fluctuation Monitoring Plan

Dear Secretary:

EP Energy Massachusetts, LLC™ (formally NAEA Energy Massachusetts, LLC) owns and operates four hydroelectric stations on the Chicopee River. Specifically Dwight Station (FERC Project No. 10675), Red Bridge (FERC Project No. 10676), Putts Bridge (FERC Project No. 10677), and Indian Orchard (FERC Project No. 10678). The attached plan is being filed to outline EP Energy Massachusetts, LLC. measures to ensure compliance with USFWS Terms and Conditions dated January 15, 2000, and MDFW Terms and Conditions dated February 15, 2000.

The plan has been reviewed by the US Fish and Wildlife Service, Massachusetts Department of Environmental Protection, and the Massachusetts Division of Fisheries and Wildlife. As of a February 8, 2012 conference call, all parties agreed the plan meets the minimum flow and impoundment fluctuation requirements of the license exemption order.

Sincerely,

David Schmidt
Senior Station Engineer
EP Energy Massachusetts, LLC.

Attachments: Min Flow Plan-02-08-2012 , Min Flow Plan-02-08-2012-Appendix
cc: John Bahrs, Cynthia Lane
cc via email: Kim Marsili, Chung-Yao Hsu (FERC)

EP ENERGY MASSACHUSETTS, LLC™

CHICOPEE RIVER PROJECTS

MINIMUM FLOW AND IMPOUNDMENT FLUCTUATION MONITORING PLAN

FOR

FERC PROJECT NO. 10675 - DWIGHT
FERC PROJECT NO. 10676 - RED BRIDGE
FERC PROJECT NO. 10677 - PUTTS BRIDGE
FERC PROJECT NO. 10678 - INDIAN ORCHARD

FEBRUARY 2012

INTRODUCTION

EP Energy Massachusetts, LLC™ (Essential Power™) owns and operates the Dwight Project (FERC No. 10675), the Red Bridge Project (FERC No. 10676), the Putts Bridge Project (FERC No. 10677), and the Indian Orchard Project (FERC No. 10678), known collectively as the Chicopee River Projects, located on the Chicopee River in Massachusetts. The projects are required to operate under the Terms and Conditions established by the US Fish and Wildlife Service (USFWS) and the Massachusetts Division of Fisheries and Wildlife (MDFW). Each project's Terms and Conditions limit the impoundment fluctuation and require the release of minimum flows into the bypass river reaches. The projects currently operate under an interim agreement outlined in the April 3, 1997 MDFW letter.

The USFWS and MDFW modified the Terms and Conditions for the projects by letters dated January 27, 2000 and February 15, 2000 respectively (copies in Appendix A). MDFW Condition 6 (Condition 5 for USFWS) required the submission of a plan for monitoring project impoundment level and instantaneous bypass flow releases. By letter dated October 5, 2001 a draft of this plan was distributed to the MDFW and USFWS for review and comment. Comments received from the agencies are provided in Appendix B and have been addressed in this final plan.

As requested by the MDFW and USFWS Terms and Conditions, this plan includes the following information:

(1) Details of the flow release structures and locations;
(2) Descriptions of the mechanisms used to monitor head pond elevations and minimum flows;
(3) Specifications of how often maintenance and calibration of the monitoring and recording equipment will take place;
(4) Description of how bypass flows will be maintained during any periodic maintenance activities that require the impoundment to be drawn down below the level of the flow release structures, and;
(5) How frequently and in what form the data are recorded.

Appendix C contains sample calculations used to determine the settings for the release mechanisms at the four projects.

DWIGHT (FERC NO. 10675)

Dwight Station is located at river mile 1.2 on the Chicopee River in the City of Chicopee. The station was constructed in 1920 and was most recently purchased in 2008 by Essential Power from Consolidated Edison Energy of Massachusetts, LLC. The station has 3 units, each rated for 480 KW, with hydraulic capacities of 254 cfs.

MDFW Condition 2 (Condition 3 of USFWS) for the Dwight Project requires the release of a minimum flow of 258 cubic-feet-per-second (cfs) (or inflow, if less) at the Dwight Dam. The flashboards have permanently been removed from the facility, so minimum flows are passed over the dam crest. Revised MDFW Condition 3 (Condition 4 of USFWS) limits impoundment draw down to a minimum of five inches above the dam crest, except for system emergencies or annual energy audits.

Impoundment Fluctuation

Impoundment levels are continuously monitored through the use of an electronic pressure transducer located on the south shoreline, slightly upstream of the canal gatehouse. Documentation of compliance with the impoundment limits is supplied by electronic recording of the impoundment level in addition to instantaneous visual displays in the canal gatehouse. The canal headgates are controlled by a Programmable Logic Controlling (PLC) device located within the canal gate house that adjust the headgate opening based upon pond level, canal level and unit operational status. The pond level control is proportional–integral–derivative **(**PID) based and is programmed to maintain a pond level of El. 77.0’; 5 inches above the permanent spillway crest level. As the pond level increases, the system increases unit load and/or brings additional units online. As the pond level falls, load is decreased and units are taken offline. The PLC continually monitors pond level and records the pond level using a strip chart as the primary recording mechanism. The sensitivity of the measurement is +/- 0.01 ft. As a secondary monitoring system, a data logger records the pond elevations every 15 minutes. The flashboards on the dam at Dwight have been removed, the minimum flow release is provided by overtopping the dam. The project’s turbines operate in an automatic mode using impoundment level controls which curtail operation when the lower impoundment level limits are reached and do not resume operation until impoundments levels are reestablished within the operable limits.

Release Mechanism

Minimum flows are released over the dam's spillway. The appropriate flow release is controlled by maintaining a headpond 5 inches above the crest of the spillway. All flows pass directly into the bypass reach**.**

During infrequent impoundment draw down for major dam repairs minimum flows will be maintained. The minimum flow release mechanism will be outlined in a letter sent prior to the impoundment draw down.

Instrumentation Maintenance and Calibration

Maintenance to the monitoring system is performed on an as-needed basis with calibration of the instruments being performed approximately every two years. At a minimum, operators visit the project approximately twice per week to confirm proper station operation. The station is also equipped with unit alarms to notify operational personnel of equipment malfunctions.

RED BRIDGE (FERC NO. 10676)

Red Bridge Hydro Station is located at river mile 15.2 on the Chicopee River in the towns of Wilbraham, Ludlow, and Palmer. The station was constructed in 1901 and was most recently purchased in 2008 by Essential Power from Consolidated Edison Energy of Massachusetts, LLC. The station has 2 units, each rated for 1,800 KW, with hydraulic capacities of 615 cfs.

MDFW Condition 2 (Condition 3 of USFWS) for the Red Bridge Project requires the release of a minimum flow of 237 cubic-feet-per-second (cfs) (or inflow, if less) at the project's spillway. MDFW Condition 3 (Condition 4 of USFWS) limits impoundment drawdown to 1-ft below the crest of the dam (El. 272.24) from April 1 to June 30, and a 2-ft impoundment draw down below the crest of the dam from July 1 to March 30, except for system emergencies or annual energy audits.

Impoundment Fluctuation

Impoundment fluctuations will be measured through the use of an electronic pressure transducer located upstream of the canal headgates. Documentation of compliance with the impoundment limits will be by electronic recording of the impoundment level in addition to instantaneous visual displays in the powerhouse. Essential Power limits impoundment draw down through the use of the project's turbines. The project's turbines operate in an automatic mode using pond level controls which curtail operation when the minimum impoundment level limits are reached and do not resume operation until acceptable operating impoundment levels are reestablished.

Release Mechanism

Essential Power has installed a bottom discharge gate at the southern end of the spillway to permit minimum flow release within the permitted impoundment fluctuations. The gate is 7 ft. wide and 8.5 ft. high with a sill elevation of 264.74 (7.5 feet below crest). The gate is equipped with an electric screw stem actuator capable of manual operation in the event of power

loss. The gate is electronically controlled by a PLC device. The PLC continuously monitors impoundment level elevations and gate positions will be adjusted automatically over the range of impoundment fluctuations to consistently release the minimum flow of 237 cfs. The impoundment level indicator is located in the impoundment adjacent to the canal headgate house. The pond level and minimum flow gate position are continuously recorded using strip chart mechanism. The sensitivity of the measurement is +/- 0.01 ft. A secondary data logger is used to record the pond level every 15 minutes, if required.

During periods of gate maintenance or malfunction, minimum flows will be maintained by spilling flows over the dam spillway maintaining a pond level 5 inches above the crest level when the units are generating. During infrequent impoundment draw down for major dam repairs minimum flows will be maintained. The minimum flow release mechanism will be outlined in a letter sent prior to the impoundment draw down.

Instrumentation Maintenance and Calibration

Maintenance to the system is performed on an as-needed basis with calibration of the instruments being performed approximately every two years. As a minimum, operators visit the project approximately twice per week to confirm proper station operation. The station is also equipped with various alarms to notify operations personnel of equipment malfunctions.

PUTTS BRIDGE (FERC NO. 10677)

Putts Bridge Hydro Station is located at river mile 9.2 on the Chicopee River in the town of Ludlow and the City of Springfield. The station was constructed in 1918 and was most recently purchased in 2008 by Essential Power from Consolidated Edison Energy of Massachusetts, LLC. The station has 2 units, each rated for 1,600 KW, with hydraulic capacities of 725 cfs.

Revised MDFW Condition 2 (Condition 3 of USFWS) for the Putts Bridge Project requires the release of a minimum flow of 25 cubic-feet-per-second (cfs) (or inflow, if less) at the project's bypass reach. MDFW Condition 3 (Condition 4 of USFWS) limits drawdown to 1-ft below the top of flashboards (El. 205.25) from April 1 to June 30, and a 2-ft draw down below the top of flashboards from July 1 to March 30, except for system emergencies or annual energy audits.

The revised condition regarding the 25-cfs minimum flow amount was noted as being subject to change based on the results of a water quality study conducted in the bypass. The study results were issued to the MDFW and USFWS on November 6, 2000. The water quality study concluded that the 25-cfs flow maintained water quality standards within the bypass and an increase was not warranted.

Impoundment Fluctuations

Impoundment fluctuations are measured through the use of electronic pressure transducers. Documentation of compliance with the impoundment limits is supplied by hourly strip charts recording pond levels in addition to instantaneous visual displays in the powerhouse. Essential Power limits impoundment draw down through the use of the project's turbines. The project's turbines operate in an automatic mode using impoundment level float controls which curtail operation when the lower impoundment level limits are reached and do not resume operation until operating impoundment levels are reestablished.

Release Mechanism

Minimum flows are released through a single, top discharge gate located on the dam's north abutment. The steel gate is 6 ft. wide and 8 ft. high and is capable of opening approximately 4- feet below the dam crest. The gate is electronically operated, and controlled by a PLC (located in the powerhouse) which automatically adjust the gate opening with fluctuating impoundment elevations to maintain a constant discharge over the top of the gate (approximately 15 inches or 25 cfs). The PLC continuously monitors and records impoundment level elevations and gate position through the use of strip charts. The sensitivity of the measurement is +/- 0.01 ft. In addition, an impoundment level indicator is located at the head gate structure adjacent to the gate.

During periodic maintenance activities to the minimum flow gate flows are discharged over the dam crest. During infrequent impoundment draw down for major dam repairs minimum flows will be maintained. The minimum flow release mechanism will be outlined in a letter sent prior to the impoundment draw down.

If a situation occurs where the headpond elevation is low, and the inflow into the site is less than the minimum flow then, the station is taken offline and the PLC regulates the min flow gate to inflow by maintaining pond level. Units are left offline until river flows return and the pond is allowed to refill.

Instrumentation Maintenance and Calibration

Maintenance to the monitoring and control systems is performed on an as-needed basis with calibration of the instruments being performed approximately every two years. As a minimum, operators visit the project approximately twice per week to confirm proper station operation. The station is also equipped with alarms to notify operations personnel of equipment malfunctions. These alarms include malfunction of the minimum flow gate and an alarm to designate that the gate control is in manual versus automatic mode.

INDIAN ORCHARD (FERC NO. 10678)

Indian Orchard Station is located at river mile 7.8 on the Chicopee River in the City of Springfield and the Town of Ludlow. The station was constructed in 1896 and was most recently purchased in 2008 by Essential Power from Consolidated Edison Energy of Massachusetts, LLC. The station has 2 units, Unit 3 rated for 1,500 KW, with a hydraulic capacity of 625 cfs; and Unit 4 rated for 2,200 KW, with a hydraulic capacity of 900 cfs.

MDFW Condition 2 (Condition 3 of USFWS) for the Indian Orchard Project requires the release of a minimum flow of 247 cubic-feet-per-second (cfs) (or inflow, if less) at the Indian Orchard Dam. Revised MDFW Condition 3 (Condition 4 of USFWS) limits drawdown to 0.5-ft below the top of the flashboards (or dam crest if boards are out) from April 1 to June 30. Drawdowns are limited to 1-ft below the top of the flashboards (or dam crest if boards are out) from July 1 to March 30, except for system emergencies or annual energy audits.

Impoundment Fluctuations

Impoundment fluctuations are measured through the use of electronic pressure transducers. The transducer is located upstream of the gatehouse and continually monitors and records impoundment elevation on strip charts. Documentation of compliance with the minimum flow requirement is supplied by strip charts that continuously monitor the pond level in addition to instantaneous visual displays in the powerhouse. The sensitivity of the measurement is +/- 0.01 ft. A data logger also records the head pond level every 15 minutes.

Essential Power currently controls impoundment levels through the use of the project's turbines. The project's turbines operate in an automatic mode using impoundment level controls that curtail operation when the impoundment limits are reached. Unit operation does not resume until acceptable impoundment levels are reestablished.

Release Mechanism

Minimums flows are released through the use of two canal drainpipes, located immediately downstream of the canal headgates, on the north side of the canal. Each drainpipe is

36-inch in diameter, corrugated metal, and has an invert of El.151.7' (approximately 10' below the top of flashboards). Each pipe is equipped with a 2-ft-6-inch square entrance control gate that is automatically operated based on pond level. The control gates are fully opened for pond levels at or above elevation 160.8' (while the units are generating). If impoundment levels begin or continue to drop below elevation 160.5' (unit motoring setting), the gates close in approximately 5% increments to restrict pond levels from dropping further. This control feature allows the passage of inflows to the project until inflows exceed the 247 cfs.

During any periodic maintenance activities that require the canal to be dewatered, project generation is discontinued and river flows are passed over the dam spillway. Periodic maintenance to Flashboards requires the pond level be lowered to approximately 1 foot below the crest of the dam. During these activities, flows will be released via the canal drain gates. Flows will be subsidized with a pump to ensure minimum flows are maintained. During infrequent impoundment draw down for major dam repairs minimum flows will be maintained. The minimum flow release mechanism will be outlined in a letter sent prior to the impoundment draw down.

Instrumentation Maintenance and Calibration

Maintenance to the impoundment level and drainpipe control gate systems is performed on an as-needed basis with calibration of the instruments being performed approximately every two years. As a minimum, operators visit the project approximately twice per week to confirm proper station operation. The station is also equipped with alarms to notify operations personnel of equipment malfunctions.

OTHER PROVISIONS

As indicated in the new Condition 10, Essential Power will attempt to maintain minimum flow releases under all operating conditions. Unless impossible (i.e. emergency circumstances or equipment malfunction), Essential Power will obtain written authorization from the MDFW and USFWS prior to any interruption of the minimum flow and impoundment fluctuation limits greater than 24 hours. If minimum flows or impoundment levels can not be maintained at any time for a duration greater than 24 hours (aside from board maintenance or replacement), Essential Power will notify the MDFW and USFWS within ten days of the violation. The notification will include a discussion of the reasons for the violation and the corrective actions taken by Essential Power.

Data on impoundment elevation, station output, and min flow gate settings will be made available to the MDFW and USFWS within 30 days of the agency's request. Essential Power will retain data on impoundment elevation, unit output, and gate settings for a 3 year period.

Summary of Operating Conditions and Pertinent Data:

	Dwight	Red Bridge	Putts Bridge	Indian Orchard
Req'd Flow (cfs)	258 (or inflow)	237 (or inflow)	25 (or inflow)	247 (or inflow)
Top of Boards	None	None	205.25	161.0
Dam Crest	76.5'	272.24	203.58	159.35
Gate Sill El	Not Applicable	264.74	199.74	151.7
Drawdown limits	5" overtopping required	1-ft (4/1-6/30) 2-ft (7/1 – 3/30)	1-ft (4/1-6/30) 2-ft (7/1 – 3/30)	0.5-ft (4/1-6/30) 1-ft (7/1 – 3/30)
Release Mechanism(s)	Spillway Overtopping	Bottom discharge gate and/or Spillway	Spillway and/or Top discharge gate	Spillway and/or 2 Canal drain pipes

APPENDIX A

REVISED TERMS AND CONDITIONS

United States Department of the Interior

FISH AND WILDLIFE SERVICE

New England Field Office
22 Bridge Street, Unit #1
Concord, New Hampshire 03301-4986

REF: FERC Nos. 11675 - Dwight
11676 - Red Bridge
11677 - Putts Bridge
11678 - Indian Orchard
Consolidated Edison Energy Massachusetts, Inc.

January 27, 2000

Mark Noyes
CEEMI
111 Broadway, 16th Floor
New York, NY 10006

Dear Mr. Noyes:

This is in response to the Federal Energy Regulatory Commission's December 29, 1999 Order Amending Exemptions for the Red Bridge, Putts Bridge, Indian Orchard and Dwight Projects, located on the Chicopee River in Massachusetts. We originally were going to respond to the November 23, 1999 memorandum prepared by Kleinschmidt Associates which provides the results of an assessment of the effect operations at Putts Bridge has on the ability of Indian Orchard to meet its minimum flow requirement. As the FERC order addresses and accepts the findings of the assessment, we instead will comment on modifications to the original terms and conditions we prescribed for the exemptions that we believe are necessary, given that minimum flows and headpond fluctuations have changed at some sites.

As originally exempted, each project had specific minimum flows and allowable impoundment drawdowns.

Originally Exempted

- Red Bridge
  237 cfs min. flow (or inflow, if less), 1-ft. drawdown April 1 - June 30 and 2-ft. from July 1 - March 30
- Putts Bridge
  247 cfs min. flow (or inflow, if less), 1-ft. drawdown April 1 - June 30 and 2-ft. from July 1 - March 30
- Indian Orchard
  247 cfs min. flow (or inflow, if less), 1-ft. drawdown year-round

- Dwight
  258 cfs min. flow (or inflow, if less), 1-ft. drawdown year-round

Proposed

- Red Bridge
  237 cfs min. flow (or inflow, if less), 1-ft. drawdown April 1- June 30 and 2-ft. from July 1 - March 30.
- Putts Bridge
  25 cfs min. flow (or inflow, if less), 1-ft. drawdown April 1- June 30 and 2-ft. from July 1 - March 30.
- Indian Orchard
  247 cfs min. flow (or inflow, if less), 0.5-ft. drawdown April 1- June 30 and 1-ft. drawdown from July 1 - March 30.
- Dwight
  258 cfs min. flow (or inflow, if less), 0.25-ft. drawdown when boards are up and no fluctuation when boards are down.

As originally exempted, the mandated flows were to be released via special minimum flow turbines. This idea was subsequently found to be uneconomical, and alternative release mechanisms were investigated. Also, in order to meet the requirements for being exempted, project capacity upgrades are necessary. CEEMI submitted a development plan in June, 1999 that outlined how upgrading the existing facilities would result in meeting that criterion.

To date, we believe the following issues have been resolved to our satisfaction:

- Bypass flow rates and release mechanisms at each project, with the exception of Putts Bridge.
- Impoundment fluctuation levels. The proposed changes to limit drawdowns at Indian Orchard to 0.5-ft from April 1 - June 30, and at Dwight to within 0.25-ft. when boards are up, should ensure that continuous and stable minimum flows are maintained below those projects.
- Proposed capacity upgrades. None of the upgrades should influence the minimum flows or drawdown limits for each project.

Two issues that remain outstanding include:

- The Putts Bridge bypass flow. We never approved the reduced flow as a permanent measure. Before approving this change as a permanent condition of the exemption, a water quality study must be performed to verify that the lower flow will protect water quality in the bypass reach. It is our understanding that the study will occur this summer. Once we receive the study results we will make a final decision on the minimum bypass flow needed at Putts Bridge.
- A revised Monitoring Plan. A condition of each exemption was the development of a plan to monitor headpond elevations and bypass flows. On March 11, 1993 the previous owner of the projects submitted a Monitoring Plan for our review. Since the original plans were filed and approved, major changes in the methods of releasing the bypass flows have been made

at the projects, requiring the development of a revised Monitoring Plan. You should provide us with a plan that (1) details the flow release structures and locations, (2) describes the mechanisms used to monitor headpond elevation and minimum flows, (3) specifies how often maintenance and calibration of the monitoring and recording equipment takes place, (4) states how bypass flows will be maintained during any periodic maintenance activities that require the impoundment to be drawn down below the level of the flow release structures, and (5) states how frequently and in what form the data are recorded. A calculation sheet that verifies the discharge of each release structure (i.e., slide/canal gate, board notches and dam spill) under all operating ranges should be included.

Per Condition 8 of the Exemptions from Licensing, we hereby modify our original terms and conditions for the subject exemptions as follows:

Red Bridge

Modify the following conditions to read:

5. The Exemptee shall, within six months from the date of issuance of the Order Amending Exemptions, present to the Fish and Wildlife Service for approval, a plan for monitoring project impoundment level and instantaneous bypass flow releases. Following approval of the plan, the Exemptee shall measure and record impoundment level and flows according to the plan and provide records of these data to the Fish and Wildlife Service within 30 days from a request for the records.

The following new condition is to be added to the original nine.

10. In the event that any dam maintenance or emergency drawdown is required, the Exemptee shall continue to operate the project such that the minimum flows are maintained downstream of the project at all times. If during reservoir refilling, inflow to the project is less than the required minimum flow, the Exemptee shall withhold not more than 10% of project inflow.

All other conditions are to be retained in their entirety.

Putts Bridge

Modify the following conditions to read:

3. An interim minimum flow of 25 cubic feet per second, or inflow to the project, whichever is less, shall be continuously released at the project dam to the bypassed reach. This release may be modified if results of a water quality study indicate that 25 cfs is insufficient to protect water quality in the bypass reach.

5. The Exemptee shall, within six months from the date of issuance of the Order Amending Exemptions, present to the Fish and Wildlife Service for approval, a plan for monitoring project impoundment level and instantaneous bypass flow releases. Following approval of the plan, the Exemptee shall measure and record impoundment level and flows according

to the plan and provide records of these data to the Fish and Wildlife Service within 30 days from a request for the records.

The following new condition is to be added to the original nine.

10. In the event that any dam maintenance or emergency drawdown is required, the Exemptee shall continue to operate the project such that the minimum flows are maintained downstream of the project at all times. If during reservoir refilling, inflow to the project is less than the required minimum flow, the Exemptee shall withhold not more than 10% of project inflow.

All other conditions are to be retained in their entirety.

Indian Orchard

Modify the following conditions to read:

4. The exemptee shall operate the project to limit drawdown of the project impoundment to no more than 0.5-feet below the top of the flashboards (or dam crest if boards are out) from April 1 through June 30. From July 1 through March 30, the Exemptee shall limit drawdown to no more than one foot below the top of the flashboards (or dam crest if boards are out).

5. The Exemptee shall, within six months from the date of issuance of the Order Amending Exemptions, present to the Fish and Wildlife Service for approval, a plan for monitoring project impoundment level and instantaneous bypass flow releases. Following approval of the plan, the Exemptee shall measure and record impoundment level and flows according to the plan and provide records of these data to the Fish and Wildlife Service within 30 days from a request for the records.

The following new condition is to be added to the original nine.

10. In the event that any dam maintenance or emergency drawdown is required, the Exemptee shall continue to operate the project such that the minimum flows are maintained downstream of the project at all times. If during reservoir refilling, inflow to the project is less than the required minimum flow, the Exemptee shall withhold not more than 10% of project inflow.

All other conditions are to be retained in their entirety.

Dwight

Modify the following conditions to read:

4. The Exemptee shall operate the project to limit drawdown of the project impoundment to no more than 0.25 feet below the top of the flashboards. When boards are out, the Exemptee shall maintain a minimum of five inches of spill over the dam crest to maintain the minimum bypass flow specified in Condition #3.

5. The Exemptee shall, within six months from the date of issuance of the Order Amending Exemptions, present to the Fish and Wildlife Service for approval, a plan for monitoring project impoundment level and instantaneous bypass flow releases. Following approval of the plan, the Exemptee shall measure and record impoundment level and flows according to the plan and provide records of these data to the Fish and Wildlife Service within 30 days from a request for the records.

The following new condition is to be added to the original nine.

10. In the event that any dam maintenance or emergency drawdown is required, the Exemptee shall continue to operate the project such that the minimum flows are maintained downstream of the project at all times. If during reservoir refilling, inflow to the project is less than the required minimum flow, the Exemptee shall withhold not more than 10% of project inflow.

All other conditions are to be retained in their entirety.

Thank you for this opportunity to comment. If you have any questions, please contact Melissa Grader of this office at (603) 225-1411.

Sincerely,

Michael J. Bartlett
Supervisor
New England Field Office

cc: John Labiak, CEEMI
Caleb Slater, MA DFW
FERC/DLC
FERC/OHL
Reading File
es: MGrader:1-27-00:(603)225-1411

Commonwealth of Massachusetts

Division of Fisheries & Wildlife

Wayne F. MacCallum, *Director*

February 15, 2000

RE: Chicopee River Projects:
Dwight – 11675
Red Bridge – 11676
Putts Bridge – 11677
Indian Orchard - 11678

Mark Noyes
CEEMI
111 Broadway, 16th Floor
New York, NY 10006

Dear Mr. Noyes,

The Massachusetts Division of Fisheries and Wildlife (Division) is the state agency responsible for the protection and management of the fish and wildlife resources of the Commonwealth. As such, we have prepared the following comments in response to the Federal Energy Regulatory Commission's December 29, 1999 Order Amending Exemptions for the Red Bridge, Putts Bridge, Indian Orchard, and Dwight Projects, located on the Chicopee River in Massachusetts.

As originally exempted, each project had specific minimum flows and allowable impoundment drawdowns.

Original Conditions

Red Bridge

237 cfs min. flow (or inflow, if less), 1-ft. drawdown April 1- June 30 and 2-ft. from July 1 - March 30

Putts Bridge

247 cfs min. flow (or inflow, if less), 1-ft. drawdown April 1- June 30 and 2-ft. from July 1 - March 30

Indian Orchard

247 cfs min. flow (or inflow, if less), 1-ft. drawdown year-round

Dwight

258 cfs min. flow (or inflow, if less), 1-ft. drawdown year-round

Proposed Conditions

Red Bridge

237 cfs min. flow (or inflow, if less), 1-ft. drawdown April 1- June 30 and 2-ft. from July 1 - March 30.

Putts Bridge

25 cfs min. flow (or inflow, if less), 1-ft. drawdown April 1- June 30 and 2-ft. from July 1 - March 30.

Indian Orchard

247 cfs min. flow (or inflow, if less), 0.5-ft. drawdown April 1- June 30 and 1-ft. drawdown from July 1 - March 30.

Division of Fisheries & Wildlife
Field Headquarters, One Rabbit Hill Road, Westboro, MA 01581 (508) 366-4470
An Agency of the Department of Fisheries, Wildlife & Environmental Law Enforcement

Dwight

258 cfs min. flow (or inflow, if less), 0.25-ft. drawdown when boards are up and no fluctuation when boards are down.

The original exemptions required that the minimum flows were to be released via new minimum flow turbines. This idea was subsequently found to be uneconomical, and alternative release mechanisms were investigated. The original exemptions also required project capacity upgrades. CEEMI submitted a development plan in June 1999 that outlined how upgrading the existing facilities would result in meeting that criterion.

We believe the following issues have been adequately addressed:

Minimum bypass flows and release mechanisms at each project, with the exception of Putts Bridge.

Impoundment fluctuation levels, specifically the proposed changes to limit drawdowns at Indian Orchard to 0.5-ft from April 1 - June 30, and at Dwight to within 0.25-ft. when boards are up, should ensure that continuous and stable minimum flows are maintained below those projects.

The proposed capacity upgrades should influence the minimum flows or drawdown limits for each project.

Unresolved issues:

The Putts Bridge bypass flow. We have not agreed to the reduced flow as a permanent condition of the exemption. Before we do so, a water quality study must be performed to verify that the lower flow will protect water quality in the bypass reach. It is our understanding that the study will occur this summer. Once we receive the study results we will make a final decision on the minimum bypass flow needed at Putts Bridge.

Revised Monitoring Plan. A condition of each exemption was the development of a plan to monitor headpond elevations and bypass flows. On March 11, 1993 the previous owner of the projects submitted a Monitoring Plan for our review. Since that time, major changes in the methods of releasing the bypass flows have been made at the projects. We believe that these changes require the development of a new Monitoring Plan. You should provide us with a plan that (1) details the flow release structures and locations, (2) describes the mechanisms used to monitor headpond elevation and minimum flows, (3) specifies how often maintenance and calibration of the monitoring and recording equipment takes place, (4) states how bypass flows will be maintained during any periodic maintenance activities that require the impoundment to be drawn down below the level of the flow release structures, and (5) states how frequently and in what form the data are recorded. A calculation sheet that verifies the discharge of each release structure (i.e., slide/canal gate, board notches and dam spill) under all operating ranges should be included.

Per Condition 8 of the Exemptions from Licensing, we hereby modify our original terms and conditions for the subject exemptions as follows:

Red Bridge

Modify the following conditions to read:

6. The Exemptee shall, within six months from the date of issuance of the Order Amending Exemptions, present to the Division for approval, a plan for monitoring project impoundment level and instantaneous bypass flow releases. Following approval of the plan, the Exemptee shall measure and record impoundment level and flows according to the plan and provide records of these data to the Division within 30 days from a request for the records.

The following new condition is to be added to the original nine.

10. In the event that any dam maintenance or emergency drawdown is required, the Exemptee shall continue to operate the project such that the minimum flows are maintained downstream of the project at all times. If during reservoir refilling, inflow to the project is less than the required minimum flow, the Exemptee shall withhold not more than 10% of project inflow.

All other conditions are to be retained in their entirety.

Putts Bridge

Modify the following conditions to read:

2. An interim minimum flow of 25 cubic feet per second, or inflow to the project, whichever is less, shall be continuously released at the project dam to the bypassed reach. This release may be modified if results of a water quality study indicate that 25 cfs is insufficient to protect water quality in the bypass reach.

6. The Exemptee shall, within six months from the date of issuance of the Order Amending Exemptions, present to the Division for approval, a plan for monitoring project impoundment level and instantaneous bypass flow releases. Following approval of the plan, the Exemptee shall measure and record impoundment level and flows according to the plan and provide records of these data to the Division within 30 days from a request for the records.

The following new condition is to be added to the original nine.

10. In the event that any dam maintenance or emergency drawdown is required, the Exemptee shall continue to operate the project such that the minimum flows are maintained downstream of the project at all times. If during reservoir refilling, inflow to the project is less than the required minimum flow, the Exemptee shall withhold not more than 10% of project inflow.

All other conditions are to be retained in their entirety.

Indian Orchard

Modify the following conditions to read:

3. The exemptee shall operate the project to limit drawdown of the project impoundment to no more than 0.5-feet below the top of the flashboards (or dam crest if boards are out) from April 1 through June 30. From July 1 through March 30, the Exemptee shall limit drawdown to no more than one foot below the top of the flashboards (or dam crest if boards are out).

6. The Exemptee shall, within six months from the date of issuance of the Order Amending Exemptions, present to the Division for approval, a plan for monitoring project impoundment level and instantaneous bypass flow releases. Following approval of the plan, the Exemptee shall measure and record impoundment level and flows according to the plan and provide records of these data to the Division within 30 days from a request for the records.

The following new condition is to be added to the original nine.

10. In the event that any dam maintenance or emergency drawdown is required, the Exemptee shall continue to operate the project such that the minimum flows are maintained downstream of the project at all times. If during reservoir refilling, inflow to the project is less than the required minimum flow, the Exemptee shall withhold not more than 10% of project inflow.

All other conditions are to be retained in their entirety.

Dwight

Modify the following conditions to read:

3. The Exemptee shall operate the project to limit drawdown of the project impoundment to no more than 0.25 feet below the top of the flashboards. When boards are out, the Exemptee shall maintain a minimum of five inches of spill over the dam crest to maintain the minimum bypass flow specified in Condition #3.

6. The Exemptee shall, within six months from the date of issuance of the Order Amending Exemptions, present to the Division for approval, a plan for monitoring project impoundment level and instantaneous bypass flow releases. Following approval of the plan, the Exemptee shall measure and record impoundment level and flows according to the plan and provide records of these data to the Division within 30 days from a request for the records.

The following new condition is to be added to the original nine.

10. In the event that any dam maintenance or emergency drawdown is required, the Exemptee shall continue to operate the project such that the minimum flows are maintained downstream of the project at all times. If during reservoir refilling, inflow to the project is less than the required minimum flow, the Exemptee shall withhold not more than 10% of project inflow.

All other conditions are to be retained in their entirety.

Sincerely,

Caleb Slater, Ph.D.
Anadromous Fish Project Leader

cc: John Labiak, CEEMI
Melissa Grader, USFWS
FERC

APPENDIX B

AGENCY CORRESPONCES

United States Department of the Interior

FISH AND WILDLIFE SERVICE

New England Field Office
70 Commercial Street, Suite 300
Concord, New Hampshire 03301-5087

November 6, 2001

REF: FERC Nos. 10675, 10676, 10677, 10678
Consolidated Edison Energy Massachusetts, Inc.

Alfred Nash, P.E.
Kleinschmidt Associates
75 Main Street, P.O. Box 576
Pittsfield, ME 04967

Dear Mr. Nash:

This responds to your October 5, 2001 cover letter and accompanying Minimum Flow and Impoundment Fluctuation Monitoring Plan for the Dwight, Red Bridge, Putts Bridge and Indian Orchard Projects, located on the Chicopee River in Massachusetts. The Plan was developed pursuant to revised terms and conditions submitted by this office and the Massachusetts Division of Fisheries and Wildlife (MADFW) for the project exemptions. We have reviewed the plans and have the following comments.

Dwight

Impoundment Fluctuation

Please include the impoundment level set points (stop, start and run) that will be programmed into the PLC system for both the boards-in and boards-out condition. Given the fine level of control that will be needed (within 3 inches with boards up and 5 inches with boards out), it is necessary to specify the equipment's sensitivity (e.g., +/- 0.1 ft.). Final set-points should take this margin of error into account. Also, please specify how frequently pond level is recorded, and how long the recorded readings are kept on file.

Release Mechanism

Please provide calculations that quantify how much flow the two canal sluice gates can discharge in the event of an impoundment drawdown for dam maintenance/repair. This section of the Plan should also describe how downstream flows will be maintained while the pond is being refilled.

General

Field calibration should occur as soon as possible to verify that the release structures are passing the required minimum flows. This information should be provided to both this office and the MADFW.

Red Bridge

Impoundment Fluctuation

Please include the impoundment level set-points (stop, start and run) that will be programmed into the PLC system for the April 1 to June 30, and July 1 to March 30 time periods. The equipment's sensitivity (e.g., +/- 0.1 ft.) should also be stated. Final set-points should take this margin of error into account. Also, please specify how frequently pond level is recorded, and how long the recorded readings are kept on file.

Release Mechanism

The Plan states that the PLC will continuously monitor pond levels. Please indicate how frequently the system takes readings and adjusts the gate (e.g., every 15 minutes).

We request that you provide calculations for the following:

- The depth of flow necessary to pass 237 cfs over the spillway.
- The amount of flow the canal drain gate and/or the drain gates at the units can pass in the event the pond is drawn down for major repairs or emergencies.

This section of the Plan should also describe how downstream flows will be maintained while the pond is being refilled.

General

Field calibration should occur as soon as possible to verify that the release structures are passing the required minimum flows. This information should be provided to both this office and the MADFW.

Putts Bridge

In the first paragraph, the second sentence should read, "...limits drawdown to 1-ft below the top of the flashboards from April 1 to June 30, and a 2-ft draw down below the top of the flashboards from July 1 to March 30..."

In the summary table on page 11, the dam crest elevation is listed as 203.54, but on the minimum flow gate calculation sheet it is listed as 203.58. Please clarify which elevation is correct.

Impoundment Fluctuation

Please include the impoundment level set-points (stop, start and run) that will be programmed into the PLC system for the April 1 to June 30, and July 1 to March 30 time periods. The equipment's sensitivity (e.g., +/- 0.1 ft.) should also be stated. Final set-points should take this margin of error into account. Also, please specify how frequently pond level is recorded, and how long the recorded readings are kept on file.

Release Mechanism

The Plan states that the PLC will continuously monitor pond levels. Please indicate how frequently the system takes readings and adjusts the gate (e.g., every 15 minutes).

Please provide calculations for the following:

- The depth of spill required to pass 25 cfs over the spillway.
- The amount of flow the low level sluice gate can pass.

This section of the Plan should also describe how downstream flows will be maintained while the pond is being refilled.

General

Field calibration should occur as soon as possible to verify that the release structures are passing the required minimum flows. This information should be provided to both this office and the MADFW.

Indian Orchard

Impoundment Fluctuation

This section needs to be updated to reflect the new fluctuation restrictions. As written, the sensor equipment is only programmed for a 1-ft drawdown. It must accommodate both a 0.5-ft and 1.0-ft drawdown for both board conditions. Please revise this section, and include the impoundment level set-points (stop, start and run) that will be programmed into the PLC system. The equipment's sensitivity (e.g., +/- 0.1 ft.) should also be stated. Final set-points should take this margin of error into account.

We are unclear what is meant by hourly strip charts; does this mean once per hour an impoundment elevation is recorded on a strip chart? Please specify how frequently pond level is recorded, and how long the recorded readings are kept on file.

Release Mechanism

The minimum flow release structures proposed are adequate for periods when the pond level is at or above the dam crest. The Plan needs to describe how bypass flows will be maintained during periods of normal operation when boards are out, or when the pond is drawn down below dam crest for repairs/maintenance activity.

Please include calculations indicating that the canal drain gates and/or the drain gates at the units can pass at least 247 cfs, in the event the pond is drawn down for major repairs or emergencies.

This section of the Plan should also describe how downstream flows will be maintained while the pond is being refilled.

General

Field calibration should occur as soon as possible to verify that the release structures are passing the required minimum flows. This information should be provided to both this office and the MADFW.

Thank you for this opportunity to comment. If you have any questions, please contact Melissa Grader of this office at (207) 781-8364, or e-mail at melissa_grader@fws.gov.

Sincerely,

William J. Neidermyer

William J. Neidermyer
Assistant Supervisor
Federal Activities
New England Field Office

Commonwealth of Massachusetts

Division of Fisheries & Wildlife

Wayne F. MacCallum, *Director*

November 15, 2001

RE: FERC Nos. 10675, 10676, 10677, 10678

Alfred Nash, P.E.
Kleinschmidt Associates
75 Main Street, PO Box 576
Pittsfield, ME 04967

Dear Mr. Nash,

This letter is in response to your report, *Chicopee River Projects: Minimum Flow and Impoundment Fluctuation Monitoring Plan,* dated October 2001. We have reviewed the plan and have the following comments.

For each project: How long kept for

Please specify the set points (stop, start and run) that will be programmed into the PLC systems.

Please specify how frequently the PLC systems monitor the pond elevation and/or how cont no 5 min frequently changes to gate adjustments/unit operations are made in response to this data.

Please specify how frequently the pond level will be recorded and how this data is kept. cont strip chart

Please provide calculations that quantify the flow to be released from the alternative flow devices to be used during maintenance drawdowns (i.e. how much flow will be provided via spillway or drain gates [and their settings] at the range of anticipated pond elevations).

Field calibration of minimum flows should occur as soon as possible to verify that the devices are functioning as required.

Sincerely,

Caleb Slater, Ph.D.
Anadromous Fish Project Leader

cc FERC
John Warner, USFWS
Melissa Grader, USFWS
John Labiak, CEEMI

Division of Fisheries & Wildlife
Field Headquarters, One Rabbit Hill Road, Westborough, MA 01581 (508) 792-7270 • Fax 792-7275
An Agency of the Department of Fisheries, Wildlife & Environmental Law Enforcement

APPENDIX C

CALCULATIONS

Kleinschmidt
Energy & Water Resource Consultants
141 Main St P.O. Box 650
Pittsfield, Maine 04967
Tel: 207.487.3328
Fax: 207.487.3174

Page:
Project No: 803-004
By: JSJ Date: 12-9-2011
Checked: MCS Date: 12-12-2011

Project: Chicopee River Projects - Minimum Flow
Subject: Dwight Minimum Flow

Analysis Description:
Calculating the gate settings required to release the minimum flow.

Assumptions:
Minimum flow of 258 cfs required
Flow is released through 2 canal sluice gates
Sluice gates only used when WSEL is below crest
Bottoms of fully opened sluice gates are estimated to be El. 66.5' (approximately 10-ft below crest).
Weir or Orifice flow possible
Orifice flow occurs when depth at crest (critical depth, 2/3 of head on crest) rises above bottom of fully opened sluice gate.
Formula for orifice flow: (2/3)*Cd*((2g)^0.5)*L*(((H1)^1.5)-((H2)^1.5)): H1=Head over the invert and H2=Head over the top of the gate
Formula for weir flow: C*L*H^3/2

Analysis:
Flow through canal sluice gates at a range of headpond elevations

Bare Crest/Invert Elevation (ft) =		66.5
	Top Elevation (ft) =	71.5
	Height (ft) =	5
	Width (ft) =	5
	Weir Coefficient (C) =	3
	Orifice Coefficient (Cd) =	0.64
	Gravity g (ft/s^2) =	32.2

Headpond Elev (ft)	Flow Condition	Total Flow (cfs)
66.5	Weir	0
67	Weir	5
67.5	Weir	14
68	Weir	26
68.5	Weir	39
69	Weir	53
69.5	Weir	69
70	Weir	84
70.5	Weir	101
71	Weir	117
71.5	Weir	134
72	Weir	151
72.5	Weir	168
73	Weir	184
73.5	Weir	200
74	Weir	216
74.5	Weir	231
75	Weir	245
75.5	Weir	259
76	Weir	272
76.5	Weir	285
77	Weir	296
77.5	Weir	306
78	Weir	316
78.5	Weir	324

Kleinschmidt
Energy & Water Resource Consultants

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Page:
Project No: 803-004
By: JSJ Date: 12-9-2011
Checked: MCS Date: 12-12-2011

Project: Chicopee River Projects - Minimum Flow
Subject: Putts Bridge Minimum Flow

Analysis Description:
Calculating the gate settings required to release the minimum flow.

Assumptions:
25 cfs Minimum flow requirement
Minimum flow passed through a top discharge gate
Gate is 6-ft wide and 8-ft high
Gate controlled by PLC
C from Bureau of Reclaimation Design of Small Dams p. 373
Spillway crest elevation is 203.58'
Gate Invert Elevation is 199.74'
Flashboard Elevation is 205.25'
Low Level Sluice no longer in use

Analysis:

Minimum Flow Top Discharge Gate
Effective Width
$L=L'-2(N*kp+kq)He$

Kp	0.02	
Ka	0.2	
N	2	
He	1.2	ft
L'	6	ft
L	5.424	ft

Required Gate Setting
$Q=CLH^{(3/2)}$

Q	25	cfs
C	3.3	
L	5.4	ft
H	1.25	ft

Must maintain an opening of
1'-3" to release minimum flow
of 25 cfs

Kleinschmidt
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Page:
Project No: 803-004
By: JSJ Date: 12-9-2011
Checked: MCS Date: 12-12-2011

Project: Chicopee River Projects - Minimum Flow
Subject: Red Bridge Minimum Flow

Analysis Description:
Calculating the minimum flow.

Assumptions:
237 cfs minimum flow is required
Minimum flow is passed through a minimum flow gate
Minimum flow can be passed over the spillway as an alternative
C from Bureau of Reclaimation Design of Small Dams p. 373
Spillway Crest elevation is 272.24'
Gate elevation is 264.7'
Gate is 7' wide x 8.5' high

Analysis:

Depth required to maintain minimum flow over the spillway - Backup

Effective Spillway Width
$L=L'-2(N*kp+kq)He$

Kp	0.02	
Kq	0.2	
N	2	
He	2	ft
L'	300	ft
L	299.04	ft

Required Gate Setting
$Q=CLH^{(3/2)}$

Q	237	cfs
C	2.9	
L	299.04	ft
H	0.42	ft

Must maintain 5" of overtopping to release minimum flow

Flow through minimum flow gates at a range of headpond elevations - Primary Min Flow

Bare Crest/Invert Elevation (ft) =			264.7
	Top Elevation (ft) =		273.2
		Height (ft) =	8.5
		Width (ft) =	7
	Weir Coefficient (C) =		3
	Orifice Coefficient (Cd) =		0.64
	Gravity g (ft/s^2) =		32.2

Headpond Elev (ft)	Flow Condition	Total Flow (cfs)
264.7	Weir	0
264.75	Weir	0
264.8	Weir	1
265	Weir	3
265.5	Weir	15
266	Weir	30
266.5	Weir	48
267	Weir	68
267.5	Weir	91
268	Weir	114
268.5	Weir	139
269	Weir	164
269.5	Weir	191
270	Weir	217
270.5	Weir	245
271	Weir	272
271.5	Weir	300
272	Weir	328
272.5	Weir	356
273	Weir	383
273.5	Weir	410
274	Weir	437
274.5	Weir	464
275	Weir	490

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Page:
Project No: 803-004
By: JSJ
Checked: MCS

Date: 12-9-2011
Date: 12-12-2011

Project: Chicopee River Projects - Minimum Flow
Subject: Indian Orchard Minimum Flow

Analysis Description:
Calculating the gate settings required to release the minimum flow.

Assumptions:
247 cfs minimum flow requirement
Minimum flow passed through 2-36" diameter CM pipes
Gate for minimum flow pipes is a 30" sqaure opening.
Invert of pipes is El 151.7'
Impoundment Fluctionation = 0.5-ft drawdown (4/1-6/30), 1-ft drawdown (7/1-3/30)
C based on a short pipe, from 6th edition of Elementary Fluid Mechanics p. 535

Analysis:
Checking Pipe Flow at a range of elevations
$Q=CA*\sqrt{(2gh)}$
$A=(pi*d^2)/4$

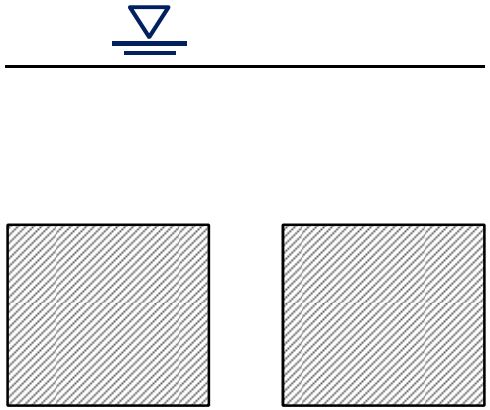
Min Flow	247	cfs
C	0.8	
A	7.07	sq-ft
d	3	ft
g	32.2	
Invert El	151.7	ft
Pipe CL El	153.2	ft

Headpond	h (ft)	Q (cfs)
161	7.8	253
160.9	7.7	252
160.8	7.6	250
160.7	7.5	249
160.6	7.4	247
160.5	7.3	245
159.6	6.4	230
158.35	5.15	206

Min Flow Calculations at
Dwight Station
Provided by US Fish and Wildlife

Dwight Dam Sluice Gate Discharge

Q_{min}	258.0 (ft^3/s)	Minimum flow release requirement
EL_1	66.5 (ft MSL)	Elevation of sluice gate sill
EL_2	71.5 (ft MSL)	Elevation of top of sluice gate opening
WS	77.0 (ft MSL)	Normal pond elevation
EL_{crest}	76.58 (ft MSL)	Dam crest elevation
H_g	5.0 (ft)	Gate opening height
W_g	5.0 (ft)	Gate opening width; also serves as L', weir length; L' modified below by Ka in tables
C_w	3.087 ($ft^{0.5}/s$)	Weir coefficient (through gate); broad-crested chute flow; also appropriate for partially submerged discharge
C_o	0.65 (-)	Orifice coefficient; p. 454 Design of Small Dams, w/development >1.25' and less than 2.5'
K_a	0.1 (-)	Abutment coefficient; p. 373 Design of Small Dams, assumes headwall at 90d to flow
K_p	0.02 (-)	Pier coefficient; p. 373 Design of Small Dams



WS	Gate Elevation and Opening (ft)										
	66.5	67.0	67.5	68.0	68.5	69.0	69.5	70.0	70.5	71.0	71.5
	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
(ft)	Flow Condition (Weir flow or Orifice flow)										
66.5	orifice	weir	weir	weir	weir	weir	weir	weir	weir	weir	weir
67.0	orifice	orifice	weir	weir	weir	weir	weir	weir	weir	weir	weir
67.5	orifice	orifice	orifice	weir	weir	weir	weir	weir	weir	weir	weir
68.0	orifice	orifice	orifice	orifice	weir	weir	weir	weir	weir	weir	weir
68.5	orifice	orifice	orifice	orifice	orifice	weir	weir	weir	weir	weir	weir
69.0	orifice	orifice	orifice	orifice	orifice	orifice	weir	weir	weir	weir	weir
69.5	orifice	orifice	orifice	orifice	orifice	orifice	orifice	weir	weir	weir	weir
70.0	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	weir	weir	weir
70.5	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	weir	weir
71.0	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	weir
71.5	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice
72.0	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice
72.5	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice
73.0	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice
73.5	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice
74.0	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice
74.5	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice
75.0	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice
75.5	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice
76.0	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice
76.5	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice
76.58	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice
77.0	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice
77.5	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice
78.0	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice
78.5	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice

WS	Gate Elevation and Opening (ft)										
	66.5	67.0	67.5	68.0	68.5	69.0	69.5	70.0	70.5	71.0	71.5
	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
(ft)	Head (ft)										
66.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
67.0	0.50	0.25	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
67.5	1.00	0.75	0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
68.0	1.50	1.25	1.00	0.75	1.50	1.50	1.50	1.50	1.50	1.50	1.50
68.5	2.00	1.75	1.50	1.25	1.00	2.00	2.00	2.00	2.00	2.00	2.00
69.0	2.50	2.25	2.00	1.75	1.50	1.25	2.50	2.50	2.50	2.50	2.50
69.5	3.00	2.75	2.50	2.25	2.00	1.75	1.50	3.00	3.00	3.00	3.00
70.0	3.50	3.25	3.00	2.75	2.50	2.25	2.00	1.75	3.50	3.50	3.50
70.5	4.00	3.75	3.50	3.25	3.00	2.75	2.50	2.25	2.00	4.00	4.00
71.0	4.50	4.25	4.00	3.75	3.50	3.25	3.00	2.75	2.50	2.25	4.50
71.5	5.00	4.75	4.50	4.25	4.00	3.75	3.50	3.25	3.00	2.75	2.50
72.0	5.50	5.25	5.00	4.75	4.50	4.25	4.00	3.75	3.50	3.25	3.00
72.5	6.00	5.75	5.50	5.25	5.00	4.75	4.50	4.25	4.00	3.75	3.50
73.0	6.50	6.25	6.00	5.75	5.50	5.25	5.00	4.75	4.50	4.25	4.00
73.5	7.00	6.75	6.50	6.25	6.00	5.75	5.50	5.25	5.00	4.75	4.50
74.0	7.50	7.25	7.00	6.75	6.50	6.25	6.00	5.75	5.50	5.25	5.00
74.5	8.00	7.75	7.50	7.25	7.00	6.75	6.50	6.25	6.00	5.75	5.50
75.0	8.50	8.25	8.00	7.75	7.50	7.25	7.00	6.75	6.50	6.25	6.00
75.5	9.00	8.75	8.50	8.25	8.00	7.75	7.50	7.25	7.00	6.75	6.50
76.0	9.50	9.25	9.00	8.75	8.50	8.25	8.00	7.75	7.50	7.25	7.00
76.5	10.00	9.75	9.50	9.25	9.00	8.75	8.50	8.25	8.00	7.75	7.50
76.6	10.08	9.83	9.58	9.33	9.08	8.83	8.58	8.33	8.08	7.83	7.58
77.0	10.50	10.25	10.00	9.75	9.50	9.25	9.00	8.75	8.50	8.25	8.00
77.5	11.00	10.75	10.50	10.25	10.00	9.75	9.50	9.25	9.00	8.75	8.50
78.0	11.50	11.25	11.00	10.75	10.50	10.25	10.00	9.75	9.50	9.25	9.00
78.5	12.00	11.75	11.50	11.25	11.00	10.75	10.50	10.25	10.00	9.75	9.50

WS	Gate Elevation and Opening (ft)										
	66.5	67.0	67.5	68.0	68.5	69.0	69.5	70.0	70.5	71.0	71.5
	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
(ft)	Orifice Flow Cross-Sectional Area (ft^2)										
66.5	0										
67.0	0	2.5									
67.5	0	2.5	5								
68.0	0	2.5	5	7.5							
68.5	0	2.5	5	7.5	10						
69.0	0	2.5	5	7.5	10	12.5					
69.5	0	2.5	5	7.5	10	12.5	15				
70.0	0	2.5	5	7.5	10	12.5	15	17.5			
70.5	0	2.5	5	7.5	10	12.5	15	17.5	20		
71.0	0	2.5	5	7.5	10	12.5	15	17.5	20	22.5	
71.5	0	2.5	5	7.5	10	12.5	15	17.5	20	22.5	25
72.0	0	2.5	5	7.5	10	12.5	15	17.5	20	22.5	25
72.5	0	2.5	5	7.5	10	12.5	15	17.5	20	22.5	25
73.0	0	2.5	5	7.5	10	12.5	15	17.5	20	22.5	25
73.5	0	2.5	5	7.5	10	12.5	15	17.5	20	22.5	25
74.0	0	2.5	5	7.5	10	12.5	15	17.5	20	22.5	25
74.5	0	2.5	5	7.5	10	12.5	15	17.5	20	22.5	25
75.0	0	2.5	5	7.5	10	12.5	15	17.5	20	22.5	25
75.5	0	2.5	5	7.5	10	12.5	15	17.5	20	22.5	25
76.0	0	2.5	5	7.5	10	12.5	15	17.5	20	22.5	25
76.5	0	2.5	5	7.5	10	12.5	15	17.5	20	22.5	25
76.58	0	2.5	5	7.5	10	12.5	15	17.5	20	22.5	25
77.0	0	2.5	5	7.5	10	12.5	15	17.5	20	22.5	25
77.5	0	2.5	5	7.5	10	12.5	15	17.5	20	22.5	25
78.0	0	2.5	5	7.5	10	12.5	15	17.5	20	22.5	25
78.5	0	2.5	5	7.5	10	12.5	15	17.5	20	22.5	25

WS	Gate Elevation and Opening (ft)										
	66.5	67.0	67.5	68.0	68.5	69.0	69.5	70.0	70.5	71.0	71.5
	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
(ft)	Weir Flow Effective Length (ft)										
66.5		5	5	5	5	5	5	5	5	5	5
67.0			4.88	4.88	4.88	4.88	4.88	4.88	4.88	4.88	4.88
67.5				4.76	4.76	4.76	4.76	4.76	4.76	4.76	4.76
68.0					4.64	4.64	4.64	4.64	4.64	4.64	4.64
68.5						4.52	4.52	4.52	4.52	4.52	4.52
69.0							4.4	4.4	4.4	4.4	4.4
69.5								4.28	4.28	4.28	4.28
70.0									4.16	4.16	4.16
70.5										4.04	4.04
71.0											3.92
71.5											
72.0											
72.5											
73.0											
73.5											
74.0											
74.5											
75.0											
75.5											
76.0											
76.5											
76.58											
77.0											
77.5											
78.0											
78.5											

WS	Gate Elevation and Opening (ft)										
	66.5	67.0	67.5	68.0	68.5	69.0	69.5	70.0	70.5	71.0	71.5
	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
(ft)	Discharge per Sluice Gate (cfs)										
66.5	0	0	0	0	0	0	0	0	0	0	0
67.0	0	7	5	5	5	5	5	5	5	5	5
67.5	0	11	18	15	15	15	15	15	15	15	15
68.0	0	15	26	34	26	26	26	26	26	26	26
68.5	0	17	32	44	52	39	39	39	39	39	39
69.0	0	20	37	52	64	73	54	54	54	54	54
69.5	0	22	41	59	74	86	96	69	69	69	69
70.0	0	23	45	65	82	98	111	121	84	84	84
70.5	0	25	49	70	90	108	124	137	147	100	100
71.0	0	27	52	76	98	117	135	151	165	176	116
71.5	0	28	55	81	104	126	146	164	181	195	206
72.0	0	30	58	85	111	134	156	177	195	211	226
72.5	0	31	61	90	117	142	166	188	209	227	244
73.0	0	33	64	94	122	149	175	199	221	242	**261**
73.5	0	34	66	98	128	156	183	209	233	256	**277**
74.0	0	35	69	102	133	163	192	219	245	**269**	**291**
74.5	0	36	71	105	138	169	199	228	255	**281**	**306**
75.0	0	37	74	109	143	175	207	237	**266**	**293**	**319**
75.5	0	39	76	112	147	181	214	246	**276**	**305**	**332**
76.0	0	40	78	116	152	187	221	254	**286**	**316**	**345**
76.5	0	41	80	119	156	193	228	**262**	**295**	**327**	**357**
76.6	0	41	81	119	157	194	229	**263**	**296**	**328**	**359**
77.0	0	42	82	122	161	198	235	**270**	**304**	**337**	**369**
77.5	0	43	84	125	165	204	241	**277**	**313**	**347**	**380**
78.0	0	44	86	128	169	209	247	**285**	**321**	**357**	**391**
78.5	0	45	88	131	173	214	253	**292**	**330**	**366**	**402**

257	Flow is below minimum required
258	Flow meets requirement

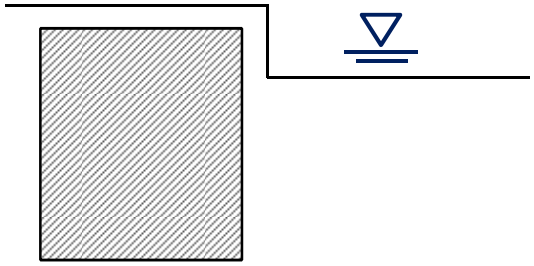
WS	Gate Elevation and Opening (ft)										
	66.5	67.0	67.5	68.0	68.5	69.0	69.5	70.0	70.5	71.0	71.5
	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
(ft)	Discharge for both Sluice Gates (cfs)										
66.5	0	0	0	0	0	0	0	0	0	0	0
67.0	0	13	11	11	11	11	11	11	11	11	11
67.5	0	23	37	29	29	29	29	29	29	29	29
68.0	0	29	52	68	53	53	53	53	53	53	53
68.5	0	34	64	87	104	79	79	79	79	79	79
69.0	0	39	74	103	128	146	107	107	107	107	107
69.5	0	43	82	117	147	172	192	137	137	137	137
70.0	0	47	90	130	165	196	221	241	168	168	168
70.5	0	50	98	141	181	216	247	274	295	200	200
71.0	0	54	104	151	195	235	271	303	330	352	231
71.5	0	57	111	161	209	252	293	329	361	389	412
72.0	0	60	117	170	221	269	313	353	390	423	452
72.5	0	63	122	179	233	284	332	376	417	454	488
73.0	0	65	128	188	245	299	350	398	442	484	521
73.5	0	68	133	196	255	313	367	418	466	511	553
74.0	0	70	138	203	266	326	383	438	489	538	583
74.5	0	73	143	211	276	339	399	456	511	563	611
75.0	0	75	147	218	286	351	414	474	532	587	639
75.5	0	77	152	225	295	363	428	491	552	610	665
76.0	0	79	156	231	304	374	442	508	571	632	690
76.5	0	81	161	238	313	386	456	524	590	653	714
76.6	0	82	161	239	314	387	458	527	593	657	718
77.0	0	83	165	244	321	396	469	540	608	674	737
77.5	0	85	169	250	330	407	482	555	626	694	760
78.0	0	87	173	256	338	417	495	570	643	714	782
78.5	0	89	177	262	346	427	507	584	659	733	803

257	Flow is below minimum required
258	Flow meets requirement

Min Flow Calculations at
Red Bridge
Provided by US Fish and Wildlife

Red Bridge Dam Min. Flow Gate Discharge

Q_{min}	237.0 (ft^3/s)	Minimum flow release requirement
EL_1	264.7 (ft MSL)	Elevation of min flow discharge gate sill
EL_2	273.2 (ft MSL)	Elevation of top of min flow discharge gate opening
EL_{crest}	272.24 (ft MSL)	Spillway crest elevation
H_g	8.5 (ft)	Gate opening height
W_g	7.0 (ft)	Gate opening width; also serves as L', weir length; L' modified below by Ka in tables
C_w	3.087	Weir coefficient; assumed for broad-crested chute flow; also appropriate for partially submerged discharge
C_o	0.65 (-)	Orifice coefficient; p. 454 Design of Small Dams, w/development >1.25' and less than 2.5'
K_a	0.1 (-)	Abutment coefficient; p. 373 Design of Small Dams, assumes headwall at 90d to flow



These tables do not include the spillway discharge.
Spillway is used only during maintenance or outages.

WS	Gate Elevation and Opening (ft)										
	264.7	265.7	266.7	267.7	268.7	269.7	270.7	271.7	272.2	272.7	273.2
	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	7.5	8.0	8.5
(ft)	Head (ft)										
264.7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
265.2	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
265.7	1.00	0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
266.2	1.50	1.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
266.7	2.00	1.50	1.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
267.2	2.50	2.00	1.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
267.7	3.00	2.50	2.00	1.50	3.00	3.00	3.00	3.00	3.00	3.00	3.00
268.2	3.50	3.00	2.50	2.00	3.50	3.50	3.50	3.50	3.50	3.50	3.50
268.7	4.00	3.50	3.00	2.50	2.00	4.00	4.00	4.00	4.00	4.00	4.00
269.2	4.50	4.00	3.50	3.00	2.50	4.50	4.50	4.50	4.50	4.50	4.50
269.7	5.00	4.50	4.00	3.50	3.00	2.50	5.00	5.00	5.00	5.00	5.00
270.2	5.50	5.00	4.50	4.00	3.50	3.00	5.50	5.50	5.50	5.50	5.50
270.7	6.00	5.50	5.00	4.50	4.00	3.50	3.00	6.00	6.00	6.00	6.00
271.2	6.50	6.00	5.50	5.00	4.50	4.00	3.50	6.50	6.50	6.50	6.50
271.7	7.00	6.50	6.00	5.50	5.00	4.50	4.00	3.50	7.00	7.00	7.00
272.2	7.50	7.00	6.50	6.00	5.50	5.00	4.50	4.00	3.75	7.50	7.50
272.7	8.00	7.50	7.00	6.50	6.00	5.50	5.00	4.50	4.25	4.00	8.00
273.2	8.50	8.00	7.50	7.00	6.50	6.00	5.50	5.00	4.75	4.50	4.25
273.7	9.00	8.50	8.00	7.50	7.00	6.50	6.00	5.50	5.25	5.00	4.75
274.2	9.50	9.00	8.50	8.00	7.50	7.00	6.50	6.00	5.75	5.50	5.25
274.7	10.00	9.50	9.00	8.50	8.00	7.50	7.00	6.50	6.25	6.00	5.75
275.2	10.50	10.00	9.50	9.00	8.50	8.00	7.50	7.00	6.75	6.50	6.25
275.7	11.00	10.50	10.00	9.50	9.00	8.50	8.00	7.50	7.25	7.00	6.75
276.2	11.50	11.00	10.50	10.00	9.50	9.00	8.50	8.00	7.75	7.50	7.25
276.7	12.00	11.50	11.00	10.50	10.00	9.50	9.00	8.50	8.25	8.00	7.75

WS	Gate Elevation and Opening (ft)										
	264.7	265.7	266.7	267.7	268.7	269.7	270.7	271.7	272.2	272.7	273.2
	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	7.5	8.0	8.5
(ft)	Flow Condition (Weir flow or Orifice flow)										
264.7	orifice	weir	weir	weir	weir	weir	weir	weir	weir	weir	weir
265.2	orifice	weir	weir	weir	weir	weir	weir	weir	weir	weir	weir
265.7	orifice	orifice	weir	weir	weir	weir	weir	weir	weir	weir	weir
266.2	orifice	orifice	weir	weir	weir	weir	weir	weir	weir	weir	weir
266.7	orifice	orifice	orifice	weir	weir	weir	weir	weir	weir	weir	weir
267.2	orifice	orifice	orifice	weir	weir	weir	weir	weir	weir	weir	weir
267.7	orifice	orifice	orifice	orifice	weir	weir	weir	weir	weir	weir	weir
268.2	orifice	orifice	orifice	orifice	weir	weir	weir	weir	weir	weir	weir
268.7	orifice	orifice	orifice	orifice	orifice	weir	weir	weir	weir	weir	weir
269.2	orifice	orifice	orifice	orifice	orifice	weir	weir	weir	weir	weir	weir
269.7	orifice	orifice	orifice	orifice	orifice	orifice	weir	weir	weir	weir	weir
270.2	orifice	orifice	orifice	orifice	orifice	orifice	weir	weir	weir	weir	weir
270.7	orifice	orifice	orifice	orifice	orifice	orifice	orifice	weir	weir	weir	weir
271.2	orifice	orifice	orifice	orifice	orifice	orifice	orifice	weir	weir	weir	weir
271.7	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	weir	weir	weir
272.2	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	weir	weir
272.7	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	weir
273.2	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice
273.7	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice
274.2	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice
274.7	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice
275.2	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice
275.7	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice
276.2	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice
276.7	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice	orifice

WS	Gate Elevation and Opening (ft)										
	264.7	265.7	266.7	267.7	268.7	269.7	270.7	271.7	272.2	272.7	273.2
	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	7.5	8.0	8.5
(ft)	Weir Flow Effective Length (ft)										
264.7		7	7	7	7	7	7	7	7	7	7
265.2		6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9
265.7			6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8
266.2			6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7
266.7				6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6
267.2				6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5
267.7					6.4	6.4	6.4	6.4	6.4	6.4	6.4
268.2					6.3	6.3	6.3	6.3	6.3	6.3	6.3
268.7						6.2	6.2	6.2	6.2	6.2	6.2
269.2						6.1	6.1	6.1	6.1	6.1	6.1
269.7							6	6	6	6	6
270.2							5.9	5.9	5.9	5.9	5.9
270.7								5.8	5.8	5.8	5.8
271.2								5.7	5.7	5.7	5.7
271.7									5.6	5.6	5.6
272.2										5.5	5.5
272.7											5.4
273.2											
273.7											
274.2											
274.7											
275.2											
275.7											
276.2											
276.7											

WS	Gate Elevation and Opening (ft)										
	264.7	265.7	266.7	267.7	268.7	269.7	270.7	271.7	272.2	272.7	273.2
	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	7.5	8.0	8.5
(ft)	Orifice Flow Cross-Sectional Area (ft^2)										
264.7	0										
265.2	0										
265.7	0	7									
266.2	0	7									
266.7	0	7	14								
267.2	0	7	14								
267.7	0	7	14	21							
268.2	0	7	14	21							
268.7	0	7	14	21	28						
269.2	0	7	14	21	28						
269.7	0	7	14	21	28	35					
270.2	0	7	14	21	28	35					
270.7	0	7	14	21	28	35	42				
271.2	0	7	14	21	28	35	42				
271.7	0	7	14	21	28	35	42	49			
272.2	0	7	14	21	28	35	42	49	52.5		
272.7	0	7	14	21	28	35	42	49	52.5	56	
273.2	0	7	14	21	28	35	42	49	52.5	56	59.5
273.7	0	7	14	21	28	35	42	49	52.5	56	59.5
274.2	0	7	14	21	28	35	42	49	52.5	56	59.5
274.7	0	7	14	21	28	35	42	49	52.5	56	59.5
275.2	0	7	14	21	28	35	42	49	52.5	56	59.5
275.7	0	7	14	21	28	35	42	49	52.5	56	59.5
276.2	0	7	14	21	28	35	42	49	52.5	56	59.5
276.7	0	7	14	21	28	35	42	49	52.5	56	59.5

WS	Gate Elevation and Opening (ft)										
	264.7	265.7	266.7	267.7	268.7	269.7	270.7	271.7	272.2	272.7	273.2
	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	7.5	8.0	8.5
(ft)	Discharge for Min. Flow Gate (cfs)										
264.7	0	0	0	0	0	0	0	0	0	0	0
265.2	0	8	8	8	8	8	8	8	8	8	8
265.7	0	26	21	21	21	21	21	21	21	21	21
266.2	0	36	38	38	38	38	38	38	38	38	38
266.7	0	45	73	58	58	58	58	58	58	58	58
267.2	0	52	89	79	79	79	79	79	79	79	79
267.7	0	58	103	134	103	103	103	103	103	103	103
268.2	0	63	115	155	127	127	127	127	127	127	127
268.7	0	68	126	173	206	153	153	153	153	153	153
269.2	0	73	137	190	231	180	180	180	180	180	180
269.7	0	77	146	205	**253**	**289**	207	207	207	207	207
270.2	0	82	155	219	**273**	**316**	235	235	235	235	235
270.7	0	86	163	232	**292**	**341**	**379**	**263**	**263**	**263**	**263**
271.2	0	89	171	**245**	**310**	**365**	**410**	**292**	**292**	**292**	**292**
271.7	0	93	179	**257**	**326**	**387**	**438**	**478**	**320**	**320**	**320**
272.2	0	97	186	**268**	**342**	**408**	**465**	**511**	**530**	**349**	**349**
272.7	0	100	193	**279**	**358**	**428**	**490**	**542**	**564**	**584**	**377**
273.2	0	103	200	**290**	**372**	**447**	**514**	**571**	**597**	**619**	**640**
273.7	0	106	206	**300**	**386**	**465**	**536**	**599**	**627**	**653**	**676**
274.2	0	109	213	**310**	**400**	**483**	**558**	**626**	**656**	**685**	**711**
274.7	0	112	219	**319**	**413**	**500**	**579**	**651**	**684**	**715**	**744**
275.2	0	115	225	**328**	**426**	**516**	**600**	**676**	**711**	**744**	**776**
275.7	0	118	231	**337**	**438**	**532**	**619**	**700**	**737**	**772**	**806**
276.2	0	121	237	**346**	**450**	**547**	**638**	**723**	**762**	**800**	**835**
276.7	0	124	**242**	**355**	**462**	**562**	**657**	**745**	**786**	**826**	**864**

236	Flow is below minimum required
237	Flow meets requirement

UNITED STATES DEPARTMENT OF THE INTERIOR

BUREAU OF RECLAMATION

DESIGN OF SMALL DAMS

A Water Resources Technical Publication

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196. Discharge Over An Uncontrolled Overflow Ogee Crest.—(a) *General.*—The discharge over an ogee crest is given by the formula:

$$Q=CLH_e^{3/2} \qquad (3)$$

where:

Q=discharge,
C=a variable coefficient of discharge,
L=effective length of crest, and
H_e=total head on the crest, including velocity of approach head, h_a.

The discharge coefficient, C, is influenced by a number of factors, such as (1) the depth of approach, (2) relation of the actual crest shape to the ideal nappe shape, (3) upstream face slope, (4) downstream apron interference, and (5) downstream submergence. The effect of these various factors is discussed in section 197.

The total head on the crest, H_e, does not include allowances for approach channel friction losses or other losses due to curvature of the upstream channel, entrance loss into the inlet section, and inlet or transition losses. Where the design of the approach channel results in appreciable losses, they must be added to H_e to determine reservoir elevations corresponding to the discharges given by the above equation.

(b) *Pier and Abutment Effects.*—Where crest piers and abutments are shaped to cause side contractions of the overflow, the effective length, L, will be less than the net length of the crest. The effect of the end contractions may be taken into account by reducing the net crest length as follows:

$$L=L'-2(NK_p+K_a)H_e \qquad (4)$$

where:

L=effective length of crest,
L'=net length of crest,
N=number of piers,
K_p=pier contraction coefficient,
K_a=abutment contraction coefficient, and
H_e=total head on crest.

The pier contraction coefficient, K_p, is affected by the shape and location of the pier nose, the thickness of the pier, the head in relation to the design head, and the approach velocity. For conditions of design head, H_o, average pier contraction coefficients may be assumed as follows:

	K_p
For square-nosed piers with corners rounded on a radius equal to about 0.1 of the pier thickness	0.02
For round-nosed piers	0.01
For pointed-nose piers	0

The abutment contraction coefficient is affected by the shape of the abutment, the angle between the upstream approach wall and the axis of flow, the head in relation to the design head, and the approach velocity. For conditions of design head, H_o, average coefficients may be assumed as follows:

	K_a
For square abutments with headwall at 90° to direction of flow	0.20
For rounded abutment with headwall at 90° to direction of flow, when $0.5H_o \geqq r \geqq 0.15H_o$	0.10
For rounded abutments where $r > 0.5H_o$ and headwall is placed not more than 45° to direction of flow	0.0

where r=radius of abutment rounding.

197. Coefficient of Discharge for Uncontrolled Ogee Crests.—(a) *Effect of Depth of Approach.*—For a high sharp-crested weir placed in a channel, the velocity of approach is small and the under side of the nappe flowing over the weir attains maximum vertical contraction. As the approached depth is decreased, the velocity of approach increases and the vertical contraction diminishes. For sharp-crested weirs whose heights are not less than about one-fifth the heads producing flow over them, the coefficient of discharge remains fairly constant with a value of about 3.3 although the contraction diminishes. For weir heights less than about one-fifth the head, the contraction of the flow becomes increasingly suppressed and the crest coefficient decreases. When the weir height becomes zero, the contraction is entirely suppressed and the overflow weir becomes in effect a channel or a broad-crested weir, for which the theoretical coefficient of discharge is 3.087. If the sharp-crested weir coefficients are related to the head measured from the point of maximum contraction instead of to the head above the sharp crest, coefficients applicable

HYDRAULIC DESIGN CRITERIA

SHEET 320-1

CONTROL GATES

DISCHARGE COEFFICIENTS

1. General. The accompanying Hydraulic Design Chart 320-1 represents test data on the discharge coefficients applicable to partial openings of both slide and tractor gates. The basic orifice equation is expressed as follows:

$$Q = C\, G_o\, B \sqrt{2gH'}$$

$H' = H - C G_o$

G_o = GATE OPENING Ht. (IN FT.)

B = GATE WIDTH (FEET)

$g = 32.2$ FT/SEC

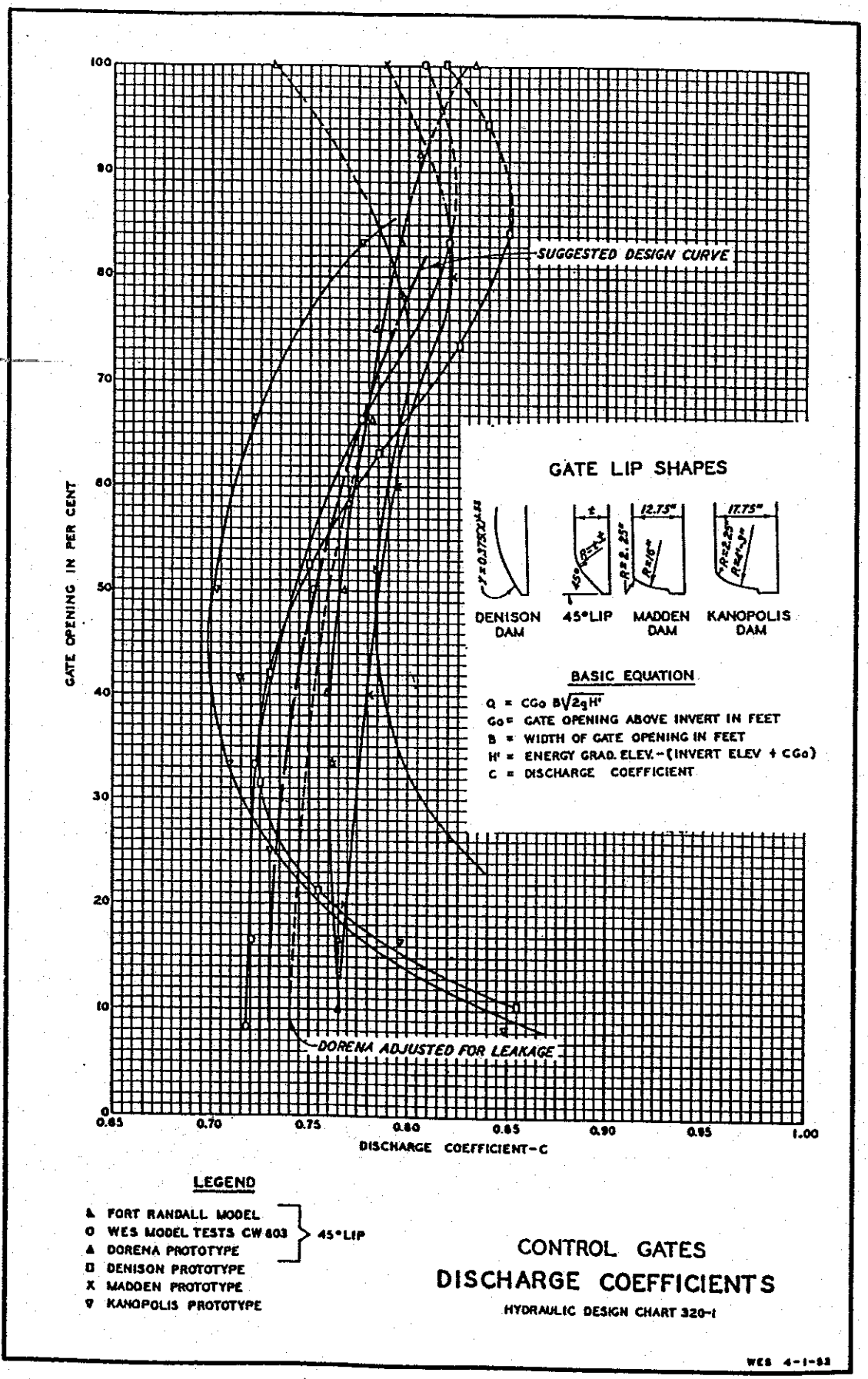
The coefficient C is actually a contraction coefficient if the gate is located near the tunnel entrance and the entrance energy loss is neglected. When the gate is located near the conduit entrance the head (H') is measured from the reservoir water surface to the top of the vena contracta. However, when the gate is located a considerable distance downstream of the conduit entrance, H' should be measured from the energy gradient just upstream of the gate to the top of the vena contracta because of appreciable losses upstream of the gate. The evaluation of H' requires successive approximation in the analysis of test data. However, the determination of H' in preparation of a rating curve can be easily accomplished by referring to the chart for C .

2. Discharge Coefficients. Discharge coefficients for tractor and slide gates are sensitive to the shape of the gate lip. Also, coefficients for small gate openings are materially affected by leakage over and around the gate. Chart 320-1 presents discharge coefficients determined from tests on model and prototype structures having various gate clearances and lip shapes. The points plotted on the 100 per cent opening are not affected by the gate but rather by friction and other loss factors in the conduit. For this reason the curves are shown by dashed lines above 85 per cent gate opening.

3. Suggested Criteria. Model and prototype tests prove that the 45° gate lip is hydraulically superior to other gate lip shapes. Therefore, the 45° gate lip has been recommended for high head structures. In the 1949 model tests leakage over the gate was reduced to a minimum. Correction of the Dorena Dam data for leakage results in a discharge coefficient curve that is in close agreement with the 1949 curve. The average of these two curves shown on Chart 320-1 is the suggested design curve. For small gate openings special allowances should be made by the designer for any expected excessive intake friction losses and gate leakage.

4. Values from the suggested design curve are tabulated below for the convenience of the designer.

Gate Opening, Per Cent	Discharge Coefficient
10	0.73
20	0.73
30	0.74
40	0.74
50	0.75
60	0.77
70	0.78
80	0.80



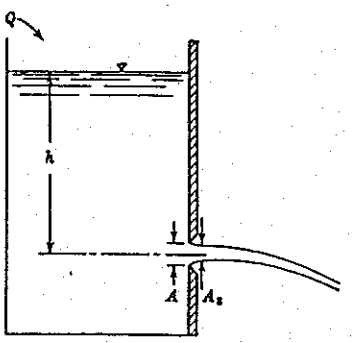
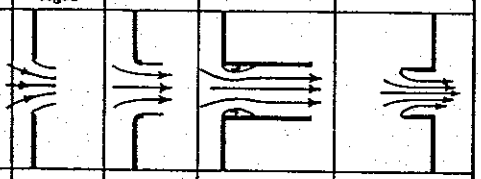


Fig. 11.28 Orifice discharging freely.

$$Q = C_c C_v A \sqrt{2g_n h} = CA \sqrt{2g_n h}$$

The dependence of the various orifice coefficients on shape of orifice is illustrated by Fig. 11.29. The coefficients given are nominal values for large orifices ($d > 1$ in. or 25 mm) operating under comparatively large heads of water ($h > 4$ ft or 1.2 m). Above these limits of head and size, various experiments have shown that the coefficients are practically constant. Coefficients for sharp-edged orifices over a wide range of Reynolds numbers are given in Fig. 11.30, which shows the same trend of values (for the same reasons) as that of Fig. 11.26. The plot of Fig. 11.30, although convenient and applicable to the flow of all fluids, has a certain limitation in orifice size caused by the action of surface tension. Surface-tension effects (although impossible to predict except in idealized situations) will increase with decreasing orifice size; the plotted values are valid only where such effects are negligible and, thus, cannot be applied to very small orifices.

Orifices and their Nominal Coefficients

	Sharp edged	Rounded	Short tube	Borda
				
C	0.61	0.98	0.80	0.51
C_c	0.62	1.00	1.00	0.52
C_v	0.98	0.98	0.80	0.98

$C = C_c \times C_v$

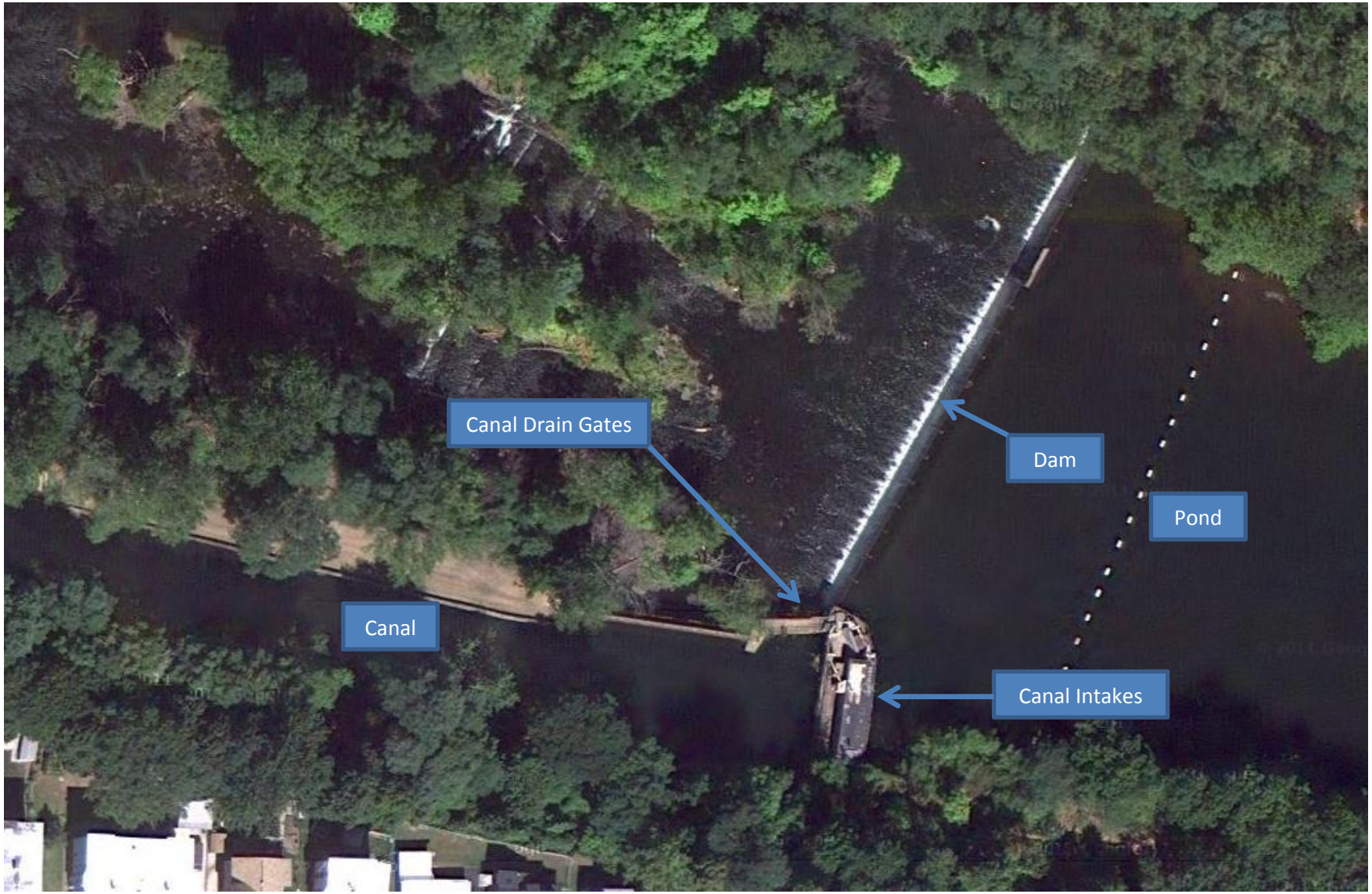
Fig. 11.29

APPENDIX D

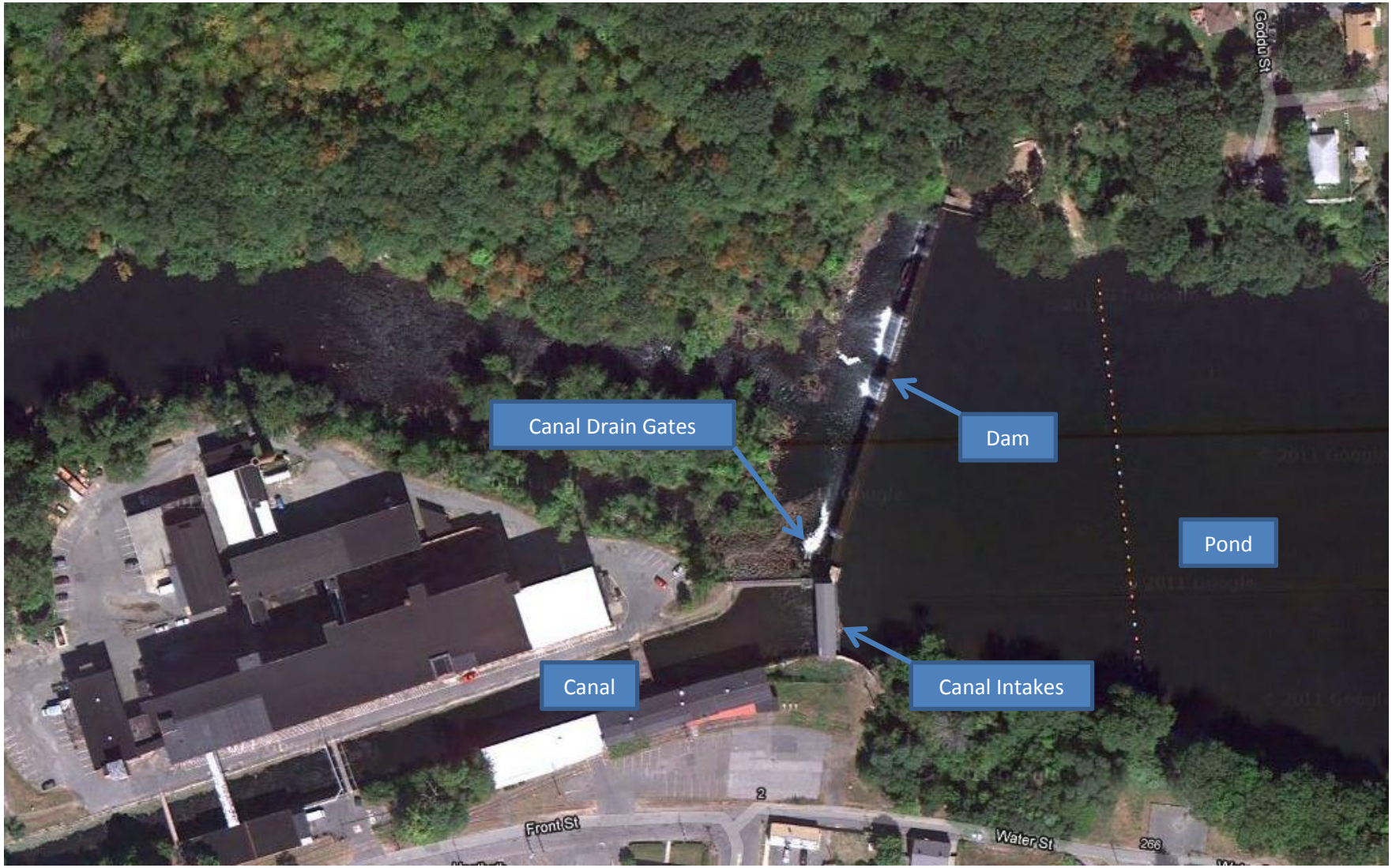
SATELITE PHOTOS

(PHOTOS CURTISEY OF GOOGLE MAPS)

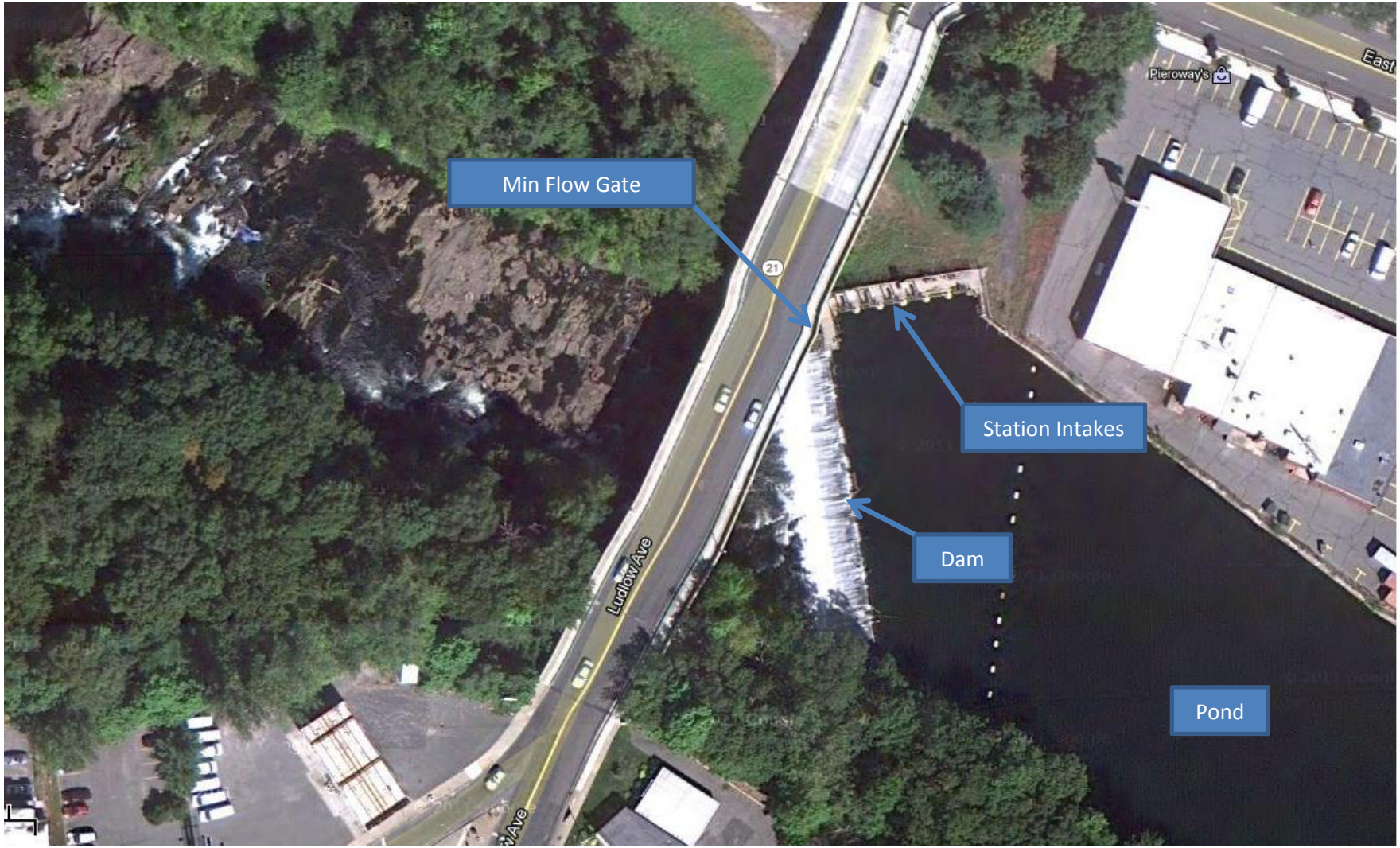
Dwight Dam



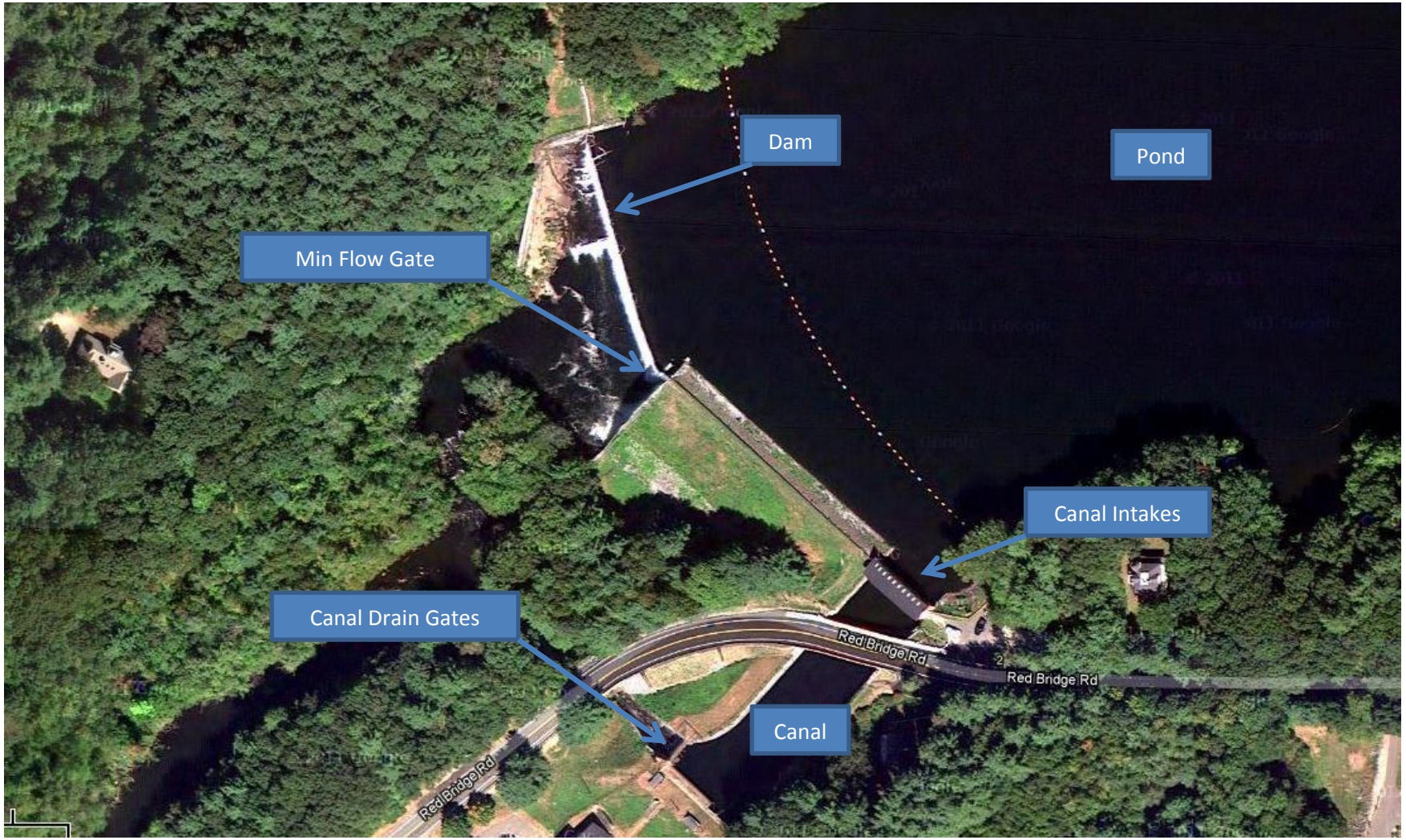
Indian Orchard Dam



Putts Bridge



Red Bridge


Dam
Pond
Min Flow Gate
Canal Intakes
Canal Drain Gates
Red Bridge Rd
Red Bridge Rd
Canal
Red Bridge Rd

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