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STATE OF COLORADO

OFFICE OF THE STATE ENGINEER
DIVISION OF WATER RESOURCES

RULES AND REGULATIONS FOR DAM SAFETY AND DAM CONSTRUCTION

September 30, 1988

DEPARTMENT OF
NATURAL RESOURCES

DIVISION OF WATER RESOURCES
OFFICE OF THE STATE ENGINEER

RULES AND REGULATIONS FOR DAM SAFETY AND DAM CONSTRUCTION

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effective:
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Office of the State Engineer
Rules and Regulations
for
Dam Safety and Dam Construction

Rule 1. <u>Title</u>:

The title of these rules and regulations is "The Rules and Regulations for Dam Safety and Dam Construction." They may be referred to herein collectively as the "Dam Safety Rules" or "Rules", and individually as a "Rule."

Rule 2. <u>Authority</u>:

These Rules are promulgated pursuant to the authority granted the State Engineer in Sections 37-87-102 and 37-87-105, C.R.S.(1973)(1987 Supp.) and Section 37-80-102(11K), C.R.S.(1973), pursuant to section 24-4-103, C.R.S.(1973).

Rule 3. <u>Scope and Purpose</u>:

A. These Rules apply to any dam constructed or used to store water in Colorado. These Rules apply to applications for review and approval of plans for the construction, alteration, modification, repair, enlargement, and removal of dams and reservoirs, quality assurance of construction, acceptance of construction, nonjurisdictional dams, safety inspections, owner responsibilities, emergency preparedness plans, fees, and restriction of recreational facilities within reservoirs. Certain structures defined in Rule 18 are exempt from these rules.

B. The purposes of these Rules are to provide for the safety of dams by establishing reasonable standards and to create a public record for reviewing the performance of a dam.

Rule 4. Definitions:

4.A. The following definitions are applicable to these Rules for Dam Safety and Dam Construction:

4.A.(1) "Alteration to, Modification of, or Repair of an Existing Dam or Appurtenant Structure" means to make different from the originally approved construction plans and specifications or current condition, except for ordinary repairs and general maintenance as defined in Rule 12.

4.A.(2) "Appurtenant Structure" means the outlet works and controls, spillways and controls, access structures, bridges, and related housings at a dam.

4.A.(3) "Breach Order" is an order issued by the State Engineer, or his designee, to remove all or part of a dam to the level of the natural ground, so it is incapable of impounding water and creating a hazard.

4.A.(4) "Capacity" is the volume of water capable of being impounded in a reservoir at the high-water line, normally expressed in acre-feet. Dead storage below the natural surface of the ground is excluded.

4.A.(5) "Classification of a Dam" is the placement of a dam into a category based upon an evaluation of the consequences of the failure of the dam absent flooding conditions, assuming the reservoir is at the high-water line. No loss of life nor significant damage is expected to occur if the increased depth of flow is two feet or less and the product of the average flood plain flow velocity and the depth of flow at a critical area is less than seven in the incremental zone.

4.A.(5)(a) A "Class I" dam is a dam for which loss of human life is expected in the event of failure of the dam.

4.A.(5)(b) A "Class II" dam is a dam for which significant damage is expected to occur, but no loss of human life is expected in the event of failure of the dam. Significant damage is defined as damage to structures where people generally live, work, or recreate, or public or private facilities exclusive of unpaved roads and picnic areas. Damage means rendering the structures uninhabitable or inoperable.

4.A.(5)(c) A "Class III" dam is a dam for which loss of human life is not expected, and damage to structures and public facilities as defined for a "Class II" dam is not expected in the event of failure of the dam.

4.A.(5)(d) A Class IV dam is a dam for which no loss of human life is expected, and which damage will occur only to the dam owner's property in the event of failure of the dam.

4.A.(6) A "Dam" is a man-made barrier, together with appurtenant structures, constructed above the natural surface of the ground for the purpose of impounding water. (For Exemptions, See Rule 18.)

4.A.(6)(a) A "Jurisdictional Dam" is a dam which impounds water above the elevation of the natural surface of the ground creating a reservoir with a capacity of more than 100 acre-feet, or creates a reservoir with a surface area in excess of 20 acres at the high-water line, or exceeds 10 feet in height measured vertically from the elevation of the lowest point of the natural surface of the ground where that point occurs along the longitudinal centerline of the dam up to the flowline crest of the emergency spillway of the dam. For reservoirs created by excavation, the vertical height shall be measured from the invert of the outlet. The State Engineer shall have final authority over determination of the vertical height.

4.A.(6)(b) A "Nonjurisdictional Dam" is less than the size and capacity of a jurisdictional dam.

4.A.(6)(c) A "Minor Dam" does not exceed 20 feet in vertical height and 100 acre feet in capacity (see Figure 1).

4.A.(6)(d) A "Small Dam" is greater than 20 feet in vertical height but equal to or less than both 40 feet and 1000 acre-feet in capacity, or is greater than 100 acre feet but equal to or less than both 1,000 acre-feet in capacity and 40 feet in vertical height (see Figure 1).

4.A.(6)(e) An "Intermediate Dam" is greater than 40 feet in vertical height but equal to or less than both 100 feet and 50,000 acre-feet in capacity, or is greater than 1,000 acre feet in capacity but equal to or less than both 50,000 acre feet in capacity and 100 feet in vertical height (see Figure 1).

4.A.(6)(f) A "Large Dam" is greater than 100 feet in vertical height, or greater than 50,000 acre feet in capacity (see Figure 1).

4.A.(6)(g) A "Diversion Dam" is a dam constructed for the purpose of diverting water from the natural stream bed into a canal, tunnel, ditch, or pipeline, and which is not designed or operated for the purpose of impounding significant amounts of water. A dam that both impounds water and diverts water into a canal, tunnel, ditch, or pipeline shall be considered a dam and is subject to these rules.

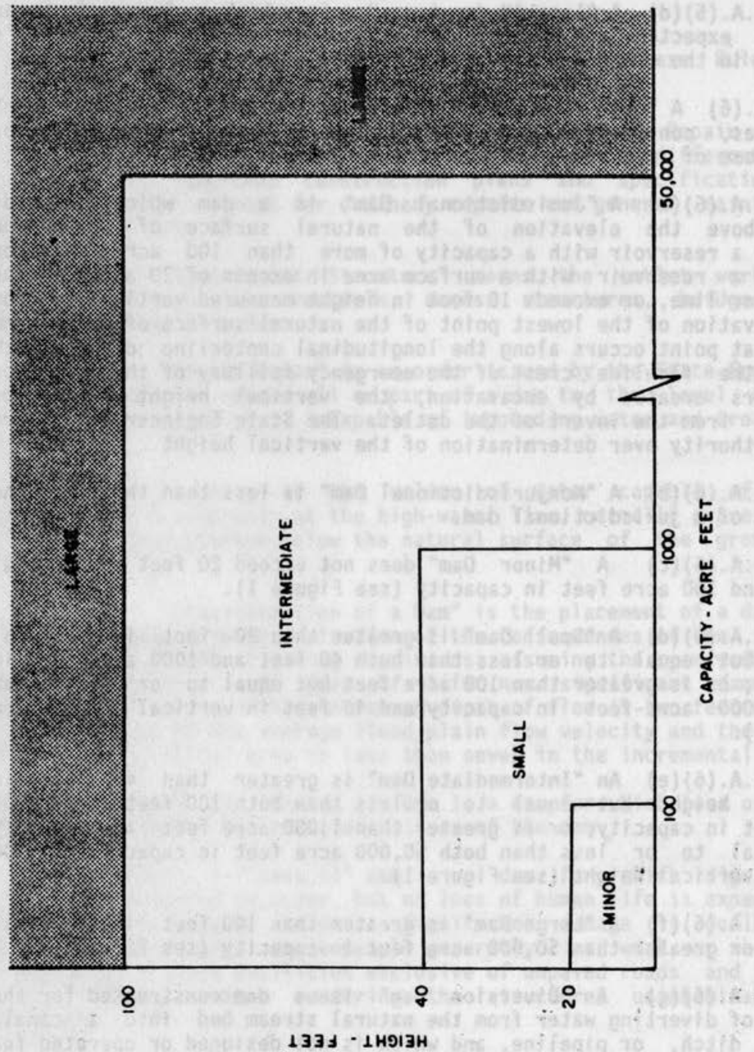

FIGURE 1. SIZES OF DAMS

4.A.(6)(h) A "Flood Control Dam" is a special purpose dam which is normally dry and has an ungated outlet structure which will drain the water impounded during the flood. The jurisdictional size and classification of the dam are determined assuming the reservoir is full to the emergency spillway.

4.A.(7) "Dam Failure Inundation Map" is a map depicting the area downstream from a dam which would reasonably be expected to be flooded in the event of the failure of a dam.

4.A.(8) "Day" as used in these Rules means a calendar day. For computation of time periods as used in these rules, Colorado Rules of Civil Procedure 6(a) shall apply.

4.A.(9) "Emergency Preparedness Plans" are written documents prepared by the dam owner, describing a detailed plan to prevent or lessen the effects of a potential dam failure.

4.A.(10) "Engineer" means a Professional Engineer registered and licensed in Colorado in accordance with Section 12-25-101, C.R.S. (1985).

4.A.(11) "Enlargement to an Existing Dam or Appurtenant Structure" means any alteration, modification, or repair which increases the vertical height of a dam as defined in Rule 4.A.(32).

4.A.(12) "Erosion Control Dam" means a dam constructed for the purpose of controlling erosion, having a vertical height not exceeding 15 feet from the bottom of the channel at the upstream toe of the dam to the crest of the spillway, having a capacity not exceeding 10 acre-feet at the emergency spillway level, and having an ungated outlet works at the two acre-foot level or lower. The water course upon which the dam is located is normally dry.

4.A.(13) "Freeboard" means the vertical dimension from the flowline crest (or bottom) of the emergency spillway to the low point on the crest of the dam.

4.A.(13a) "Residual Freeboard" means the vertical dimension between the maximum water surface elevation, during the inflow design flood for the reservoir, and the low point on the crest of the dam.

4.A.(14) "Flowline Crest" means the highest elevation of the floor of a spillway at which uncontrolled flow begins.

4.A.(15) "High Water Line" is the water surface elevation of the reservoir at the flowline crest of the emergency spillway or, if no spillway exists, at the crest of the dam.

4.A.(15a) The "Normal High Water Line" is the elevation of the flowline crest of the principal spillway or, if no principal spillway exists, the flowline crest of the emergency spillway.

4.A.(16) "Impound Water" means to store or accumulate water for immediate or future use in a reservoir.

4.A.(17) "Inflow Design Flood" means the flood hydrograph which is used to determine a spillway's hydraulic capacity as required by these regulations. (See Safety Evaluation Flood, Rule 4.A.(27)).

4.A.(18) "Livestock Water Tank Dam" means a dam constructed for the purpose of watering livestock, having a capacity not exceeding 10 acre-feet and a vertical height not exceeding 15 feet from the bottom of the channel at the upstream toe of the dam to the bottom of the emergency spillway. The dam may not be used for irrigation purposes and the water course upon which the dam is located must be normally dry.

4.A.(19) "Natural Surface of the Ground" means the undisturbed ground surface before excavation, or the undisturbed bed of the stream or river.

4.A.(20) "One-hundred-year Flood" means a potential flood which has a magnitude (peak discharge) which is expected to be equaled or exceeded on the average once during any one-hundred-year period (recurrence interval) and has a one percent chance of being equaled or exceeded during any year (0.01 exceedance probability). The terms "one-hundred-year flood," "one percent chance flood," and "intermediate regional flood" are synonymous.

4.A.(21) "Outlet" means a conduit (usually controlled by gates or valves) which is used to release impounded water from the reservoir.

4.A.(22) "Owner" means any person or entity who owns, controls, operates a dam, or proposes to construct a dam. For liability purposes, the persons actually in control of a dam shall be deemed the owner, unless notice of the true owner and their address has been filed with the State Engiener by January 1, 1985. Changes in ownership shall be filed with the State Engineer immediately.

4.A.(23) "Probable Maximum Precipitation" (PMP) means the theoretically greatest depth of precipitation for a given duration that is physically possible over a drainage basin at any specific time of year.

4.A.(24) "Reservoir" means a body of water impounded by a dam.

4.A.(25) "Restriction Order" means an order issued by the State Engineer to limit the maximum water surface elevation of the reservoir.

4.A.(26) "Routing Capacity" means the capability of a reservoir to attenuate flood inflows, and is calculated as the inflow of a flood minus both the outflow and surcharge storage for an assumed time increment measured in acre feet.

4.A.(27) "Safety Evaluation Flood" means the flood hydrograph which is used to determine an existing dam's spillway hydraulic capacity as required by these regulations.

4.A.(28) "Surcharge Storage" means the volume of water which may be impounded but not retained within a reservoir between the normal high-water line and the crest of the dam.

4.A.(29) "Safety Inspection" means an investigation by an engineer for the purpose of determining the safe storage level for a reservoir, and includes, but is not limited to, the review of previous inspections, reports, and drawings, site inspections of the dam, spillways, outlet facilities, seepage control and measurement systems, and permanent monument or monitoring installations, if any.

4.A.(30) "Safe Storage Level" means the reservoir water surface elevation at which the State Engineer has determined is the amount of water which is safe to impound in the reservoir.

4.A.(31) "Spillway" means an appurtenant structure which conducts overflows from a reservoir.

4.A.(31a) "Principal Spillway" means the primary or first-used spillway during runoff. It is designed to pass normal flows, and is not normally capable of passing the "Inflow Design Flood" by itself. It is usually an open channel, pipe, or culvert.

4.A.(31b) "Emergency Spillway" means the spillway designed to pass the "Inflow Design Flood" using the routing capacity of the reservoir. Pipe or culvert spillways are not considered to be emergency spillways for determination of vertical height unless accepted by the State Engineer.

4.A.(32) "Vertical Height" means the dimension as measured from the elevation of the lowest point of the natural surface of the ground, or from the invert of the outlet pipe if excavated into the natural ground, whichever is lower, where that point occurs along the longitudinal centerline of the dam, up to the flowline crest of the emergency spillway. For existing dams, the vertical height shall be measured by determining the slope of the foundation and height of the dam at the downstream toe and extrapolating the height of the dam to the longitudinal centerline of the dam. The formula for determining the vertical height of existing dams is: $h = h_d - f_b - sl$; where h = vertical height, h_d = height of dam from downstream toe, f_b = freeboard, s = slope of the natural surface of the ground, and l = horizontal distance from the downstream toe to the longitudinal centerline of the dam. The State Engineer shall have final authority over determination of the vertical height (see Figure 2).

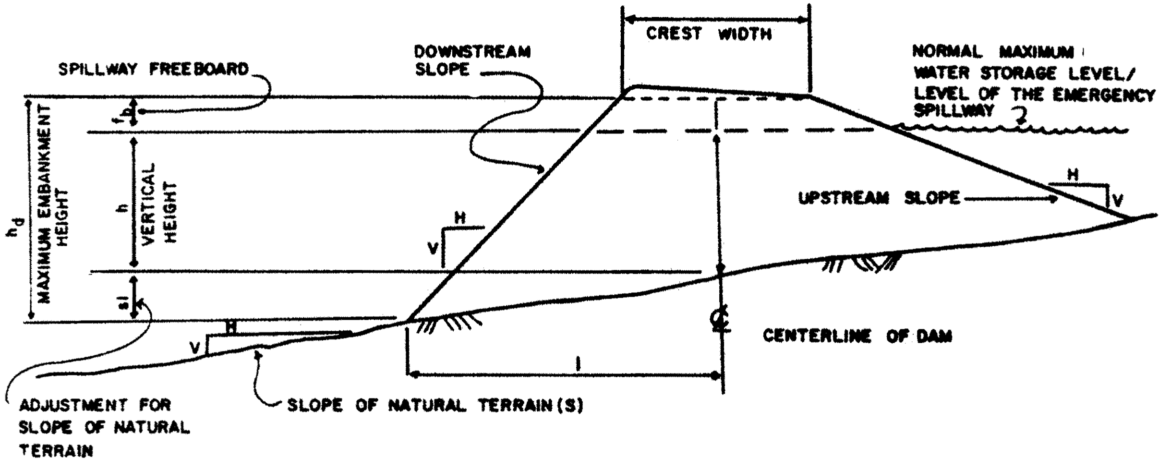

FIGURE 2. DAM MEASUREMENTS AT THE MAXIMUM CROSS SECTION (VERTICAL HEIGHT)

Rule 5. Requirements for Construction, or Enlargement, of Jurisdictional Dams or Reservoirs:

Rule 5.A. An owner proposing to construct or enlarge a jurisdictional dam or reservoir shall submit an application package, in a form acceptable to the State Engineer, and receive approval of the construction plans and specifications from the State Engineer prior to commencing construction. The application package shall be prepared by an engineer, and shall consist of the following:

1. Application Form
2. Construction Plans
3. Construction Specifications
4. Classification Report
5. Hydrology Report
6. Geotechnical Report
7. Design Report
8. Instrumentation Plan
9. Cost Estimate
10. Filing Fee

The requirements for each of these items are as follows:

5.A.(1) A completed application form provided by the State Engineer. This form will be the only information normally available to the public before the project is approved for construction.

5.A.(2) Construction drawings or plans which shall meet the following requirements:

5.A.(2)(a) The plans shall show the design of the dam and each appurtenant structure in sufficient detail so that the contractor or builder is able to construct the proposed structure from the plans and the specifications (see 5.A.[3][a]).

5.A.(2)(b) The first sheet shall include, as a minimum, the name of the dam; the county; Water Division and former Water District in which the dam is located; a list of the drawings that follow the cover sheet; the design engineer's seal (crimp type not acceptable) and signature; the State Engineer's statement and engineer's AS-CONSTRUCTED statement located in the lower right quadrant of the drawing both in the form as follows:

Approved on the ________________ day of ______________ 19__.

____
State Engineer
By: ___________________________________
Deputy

and,

These plans represent the AS-CONSTRUCTED conditions of
_______________________ dam to the best of our knowledge and judgement, based in part on information furnished by others as of the _____ day of _______________, 19___.

_____________________________ _____________________________
(Engineer's printed name) (Signature)

5.A.(2)(c) Drawings filed with the State Engineer shall be originals, or a high quality reproducible archival copy of the original, and shall be prepared in an appropriate scale so details are legible, drawn with permanent ink on high quality Mylar or equivalent, submitted in an overall size of 24 inches high and 36 inches wide.

5.A.(2)(d) Drawings shall have a minimum margin of two inches on the left and 1/2 inch on the right, top, and bottom.

5.A.(2)(e) Minimum letter size shall be 1/8 inch or 100 Leroy template or equivalent.

5.A.(2)(f) All drawing sheets shall have bar scales in order to allow scaling of reduced drawings.

5.A.(2)(g) All drawing sheets shall have in the lower right-hand corner a 1/2- by 3-inch space for the State Engineer's file number.

5.A.(2)(h) Each sheet shall have the responsible engineer's seal and signature.

5.A.(2)(i) Each sheet shall be numbered sequentially with the first sheet being sheet number one in conjunction with the total numbered sheets; e.g., 1 of 6.

5.A.(3) Construction Specifications which shall meet the following requirements:

5.A.(3)(a) The front cover of the specifications shall show the title or name of the dam (identical to the title on the plans), the county, Water Division and former Water District, in which the dam is located. The first page behind the front cover shall show the name of the dam (identical to the name on the plans), the county, Water Division and former Water District in which the dam is located, and the engineer's seal and signature, and the State Engineer's approval statement as follows:

Approved on the____________day of____________ 19___.

____
State Engineer
By:____
Deputy

5.A.(3)(b) The specifications shall be indexed.

5.A.(3)(c) Final specifications shall be bound and submitted on a good grade of white 8 1/2- by 11-inch paper.

5.A.(3)(d) The general conditions shall include statements that the plans and specifications cannot be significantly changed without the prior written approval of the State Engineer in accordance with Rule 9.A.(8).

5.A.(3)(e) The general conditions shall include the provision that construction shall not be considered complete until the state engineer has accepted the construction in writing.

5.A.(3)(f) The specifications shall provide that the owner's engineer will monitor the quality of construction as specified in Rule 9.

5.A.(3)(g) The specifications shall include as a minimum, but are not limited to, the following:

1. The quality of materials used in construction;

2. The acceptable quality of workmanship;

3. The reference to applicable standards, if any;

4. The required tests and estimated frequency of testing; and,

5. The action to be taken if unsatisfactory materials or workmanship are discovered in the construction.

5.A.(4) A classification report which complies with these rules, and sets forth the classification of the proposed dam, or for the proposed enlargement of an existing dam. A report is not required for dams which are declared as Class I; however, a dam failure inundation map will be required for the Emergency Preparedness Plan pursuant to Rule 16.A.(3). The report shall include sufficient calculations or data to establish the reasonableness of the predicted dam failure flood which may include several failure rates and sizes of breach, and an assessment of the impact of a dam failure upon the downstream floodplain. The report shall classify the dam in accordance with Rule 4.A.(5).

5.A.(4)(a) The evaluation of the effects of flood inundation in the report shall extend at least to the location downstream where the classification can be properly identified.

5.A.(4)(b) The report shall be submitted in a form acceptable to the State Engineer and shall include but not be limited to:

1. Dam failure inundation maps (except inundation maps are not required for minor dams located in remote areas where there is no development downstream of the dam);

2. Cross-sections drawn to scale showing water surface elevations at critical sections where structures are impacted as described in the classification of dams. Cross-sections shall show discharge in cubic feet per second, average velocity in feet per second, and structures located in the flooded section;

3. A tabulation of assumed parameters including Mannings "n" values for the floodplain;

4. A sensitivity analyses of the assumed "n" values and time to failure; and

5. References for all programs, data and documents used in the evaluation.

5.A.(5) A hydrology report which complies with these rules, and presents the inflow design flood for determining the spillway capacity.

5.A.(5)(a) The hydrology report shall be submitted in a form acceptable to the State Engineer and shall include but not be limited to the following information:

1. A topographical map showing the drainage area above the dam with the drainage area delineated and noted in square miles; the location of the proposed dam by quarter section, section, township, range, and principle meridian; the bearing and distance from Station 0+00 on the dam to a section corner; the name of the stream impounded, or indicate the dam is off stream and name the stream to which it is tributary, or name the drainage basin in which the dam is located; the elevation of the dam crest;

2. A description of the topography, geology, and vegetative cover of the drainage area;

3. A summary of all hydrologic parameters for the method used, the peak inflow design flood hydrograph, volume of flood, and the hazard classification of the dam;

4. A spillway discharge rating table (in cubic feet per second) for each foot of elevation above the spillway flowline crest to the crest of the dam, including the equations for determining the discharge rate; and

5. A table showing the reservoir area (in acres) and storage capacity (in acre-feet) for each foot of elevation from the invert of the outlet to the crest of the dam. Indicate the amount of dead storage (in acre-feet), elevation of the invert of the outlet, and the elevation of the flowline crest of the spillway(s). (All elevations shall be based on USCGS datum, referenced to the invert of the outlet).

5.A.(5)(b) The inflow design flood (IDF) requirements for determining the spillway capacity are summarized in the following table. These requirements may be waived for good cause shown. Spillways designed in accordance with these rules will not be required to be enlarged due to subsequent revisions to the probable maximum precipitation estimates, unless, in the opinion of the State Engineer, there is a substantial threat to public safety.

INFLOW DESIGN FLOOD REQUIREMENTS

Dam Class	I	II	III	IV
Dam Size				
Large	PMP	.75 PMP	100 YR	50 YR
Intermediate	PMP	.50 PMP	100 YR	50 YR
Small	PMP	.50 PMP	100 YR	25 YR
Minor	.50 PMP	100 YR	50 YR	25 YR

5.A.(5)(b)(I) New Large, Intermediate, and Small Class I dams and enlargements shall have spillways capable of passing, as a minimum, the inflow design flood generated by 100 percent of the Probable Maximum Precipitation, unless an incremental damage analysis demonstrates a lesser inflow design flood is applicable.

5.A.(5)(b)(II) New Minor Class I dams and enlargements shall have spillways capable of passing, as a minimum,the inflow design flood generated by 50 percent of the Probable Maximum Precipitation, unless an incremental damage analysis demonstrates a lesser inflow design flood is applicable.

5.A.(5)(b)(III) New Large Class II dams and enlargements shall have spillways capable of passing, as a minimum, the inflow design flood generated by 75 percent of the Probable Maximum Precipitation, unless an incremental damage analysis demonstrates a lesser inflow design flood is applicable.

5.A.(5)(b)(IV) New Intermediate and Small Class II dams and enlargements shall have spillways capable of passing, as a minimum, the inflow design flood generated by 50 percent of the Probable Maximum Precipitation, unless an incremental damage analysis demonstrates a lesser inflow design flood is applicable.

5.A.(5)(b)(V) New Minor, Class II and Large, Intermediate, and Small Class III dams and enlargements shall have spillways capable of passing, as a minimum, the 100-year flood as defined in Rule 5.A.(5)(d).

Rule 5.A.(5)(b)(VI) New Minor, Class III dams, and Large and Intermediate Class IV Dams and enlargements shall have spillways capable of passing the 50-year flood as defined by Rule 5.A.(5)(d).

Rule 5.A.5.(b)VII New Small and Minor Class IV dams and enlargements shall have spillways capable of passing the 25-year flood as defined by Rule 5.A.(5)(d).

5.A.(5)(b)(VIII) The minimum size spillway for all Class I, II, and III jurisdictional dams, except minor Class III, for which an incremental damage analysis shows a smaller spillway is justifiable under Rule 5.A.(5)(c), shall be capable of passing the 100-year flood as defined in Rule 5.A.(5)(d).

5.A.(5)(b)(IX) For dams whose spillway cannot pass the inflow design flood requirements defined in parts (I) through (VII) above, the engineer may as an alternative, provide documentation that overtopping of the dam by floods which exceed the spillway capacity will not cause failure of the dam.

5.A.(5)(b)(X) The minimum freeboard requirements for new or enlarged dams shall be based upon the maximum height which will prevent overtopping by wave action, or the sum of the inflow design flood maximum water surface level plus one foot of residual freeboard, or a minimum of five feet unless the State Engineer approves a lesser standard for good cause shown.

5.A.(5)(c) The Incremental Damage Analysis (IDA) used to justify an Inflow Design Flood (IDF) less than the minimum requirements of Rule 5.A.(5)(b) or Rule 6.A.(4), shall be based upon a comparison of two floods: first, a base flow flood of a magnitude which will cause overtopping failure of a dam and routing it downstream assuming no dam is in place and second, the dam failure flood due to overtopping, imposed upon the base flow flood. The spillway capacity and IDF will be acceptable where it can be shown that the dam failure flood would cause no expected additional loss of life and would not cause significant incremental flood damages downstream.

5.A.(5)(c)(I) For comparison of the two types of floods, no additional loss of life nor "significant" damage is expected in the incremental zone if the incremental increased depth of flow is two feet or less and the product of the average floodplain flow velocity (in feet per second) and the incremental depth of flood (in feet) is less than seven.

5.A.(5)(c)(II) Documentation for the IDA shall include but not be limited to: a dam break flood plotted on topographic maps of the affected areas; hydraulically appropriate cross-sections of the downstream channel showing flood stages with velocities and discharges for the two floods; incremental damage and loss of life determinations; and a summary of all hydraulic parameters. Documentation shall also include, if deemed necessary by the State Engineer, channel profiles with the various flood stages; aerial photographs of the affected areas; and computer printouts showing flood discharges, stage, and velocities with respect to time.

5.A.(5)(d) The Inflow Design Flood (IDF) shall range between the Probable Maximum Flood and the 25-year flood, with the Inflow Design Flood determined by the following methods:

5.A.(5)(d)(I) When the 100-year flood event is the appropriate Inflow Design Flood, the probable future flow shall be determined by one of the following methods:

5.A.(5)(d)(I)(A) Whenever the records basic to a determination of probable future water flows extend for a period of one hundred or more years at reliable gaging stations, the calculation of the IDF based upon those records shall be deemed conclusive. The records however, must be adjusted for historic diversions and the effects of upstream storage. If such records do not extend for a period of 100 or more years, then the determination shall be made by interpolation and correlation to a full 100 years of records by relating them to known records of known basins as similar as reasonably possible to the basin under consideration. A stream gaging station record shall be deemed reliable if made by the State of Colorado or United States as part of a regular program of either of these entities, except as to any part of such records the State Engineer shall have designated as being unreliable on the basis of facts so showing.

5.A.(5)(d)(I)(B) Whenever a determination of a 100-year flood is required at a place other than the location of a reliable stream gaging station, the determination of probable runoff at such other place shall be made by relating the probable future runoff at that place to the recorded runoff at a comparable gaging station or gaging stations by the interpolation of reasonable hydrologic, geologic, and natural vegetative factors. Unless clearly unrelated, the factors of the comparison shall include, but not be limited to, the following elements or characteristics:

1. The water basin contributing to the probable future flow at the place where probable future runoff is to be determined, considering: basin size; the altitude or altitudes of the basin; various soil permeabilities; the various vegetative covers; and the aspect of the comparable basins;

2. The known runoff as determined by reliable stream gaging stations using interpolations when necessary from comparable gaging stations and relating interpolations to the characteristics of the basin measured by the comparable gaging stations as related to the basin of runoff being determined; and

3. The slope or slopes of the terrain whose surface runoff contributes to the surface water flows at the place at which a determination of probable future surface water flows is required.

5.A.(5)(d)(I)(C) When using the gaging station records as described above, calculations shall be based on procedures outlined in the "United States Water Resources Council, "Guidelines for Determining Flood Flow Frequencies," Bulletin #17B of the Hydrology Subcommittee, Revised Edition, Interagency Advisory Committee on Water Data, U.S. Department of the Interior, Geological Survey, Office of Water Data Coordination, Reston, Virginia, 22092, March 1982, which is hereby incorporated by reference into this rule, and does not include later amendments to, or editions of, the incorporated material; or other methods as approved by the State Engineer.

5.A.(5)(d)(I)(D) Historical precipitation data of the National Weather Service may be used for determining probable future water flows, provided applicable stochastic procedures outlined in the

National Weather Service NOAA Atlas #2 "Precipitation-Frequency Atlas of the Western United States" Volume III-Colorado, U.S. Department of Commerce, NOAA, National Weather Service, Silver Springs, Maryland, 1973, which is hereby incorporated by reference into this Rule and does not include later amendments to our editions of the incorporated material; or other methods approved by the State Engineer, are used to determine the 100-year precipitation. When using precipitation data for determining probable future water flows, the analysis shall consider whether such precipitation occurred as rain or snow, and the magnitude, duration and frequency of precipitation.

5.A.(5)(d)(I)(E) The National Weather Service, NOAA, Atlas #2 "Precipitation-Frequency Atlas of the Western United States" Volume III-Colorado, U.S. Department of Commerce, NOAA, National Weather Service, Silver Springs, Maryland, 1973, is hereby incorporated by reference into this rule, and does not include later amendments to, or editions of, the incorporated material, 1973, or other documents approved by the State Engineer, may be used for determining the 100-year precipitation for calculating the 100-year flood.

Rule 5.A.(5)(d)(I)(F) Whenever a determination of the 50-year or 25-year flood is appropriate, the same principles of Rule 5.A.(5)(d) apply.

5.A.(5)(d)(II) Whenever a determination of probable future surface water flows, or the probability of frequency of their recurrence, at any place in Colorado is required by relation to a longer period than that for which there is a reliable record of flows as defined in (I) above (e.g., flows resulting from Probable Maximum Precipitation), the determination shall be made by interpolation and correlation of known records to the longer period by relating known records of water basins as similar as reasonably possible to the place of determination or basin under consideration, or by use of geologic determinations, or determining Probable Maximum Precipitation by use of other methods reasonably calculated to formulate an accurate estimate of probable future flows or the probability of frequency of their recurrence at the place of determination of such flows. The following methods or other methods approved by the State Engineer. are acceptable:

5.A.(5)(d)(II)(A) Site specific hydrometeorologic analysis, following procedures used by the National Weather Service, to transpose large historical storms to the drainage basin under consideration to determine the Probable Maximum Precipitation. Snowmelt conditions shall be considered as base flow when appropriate.

5.A.(5)(d)(II)(B) The most current Probable Maximum Precipitation estimates developed by the Office of Hydrology, National Weather Service, NOAA Hydrometeorological Report Series may be used for determining probable future flows. Snowmelt conditions shall be considered as base flow when appropriate.

5.A.(6) A geotechnical report which complies with these rules, and evaluates the stability of the foundation, dam, and the slopes of the reservoir rim, and demonstrates that sufficient material is available to construct the dam as designed. The Geotechnical report shall include, but not be limited to, the following:

5.A.(6)(a) For all classes of dams include information on the geology of the local area and dam foundation. Additionally, for Class I dams and large and intermediate size Class II dams include data on faults and the fault history which may affect the dam, the seismicity of the area and region, and a seismic evaluation of the reservoir perimeter slide potential.

5.A.(6)(b) For Class I and Class II dams foundation investigations shall include drilling to and penetration into bedrock or 1.5 times the height of the dam, whichever is less; development of drilling logs; conducting standard penetration tests; making field soils classifications; determination of the water level in each drill hole; in situ permeability; gradation tests of foundation materials especially in the area of drains; and if applicable, determination of whether liquefaction potential is present and whether clayey materials exhibit residual strength properties.

5.A.(6)(c) For Class I and Class II dams, the report shall demonstrate that adequate borrow materials are available for construction. As a minimum, the following qualitative tests shall be included:

1. Gradation of the materials;

2. Laboratory soils classifications;

3. Compressibility of soils;

4. Remolded permeability of materials;

5. Shear strength of materials (dynamic shear strength tests if applicable;

6. Proctor compaction test curves; and

7. The presence of dispersive clays.

5.A.(6)(d) For Class III dams, other than minor ones, the report shall include the field soils classification, geotechnical logs, standard penetration tests and the requirements of Rule 5.A.(6)(c) Sections (1), (2) and (6). The foundation exploration shall include drilling to, and penetration of the bedrock, or 1.5 times the height of the dam, whichever is less.

5.A.(6)(d)I Minor, Class III and all Class IV dams shall include field soils classifications as a minimum.

5.A.(6)(e) For all dams, except minor Class III and all Class IV, with a spillway located on an earth foundation, the report shall include the following:

1. Soil classification;

2. Soil profile logs along the channel extending at least five feet below the bottom of the spillway;

3. Density or bearing capacity of foundation; and

4. Gradation of soils.

5.A.(6)(f) For all dams, except minor Class III and all Class IV, with spillways located on a rock foundation, the report shall include a geologic description of the rock, including bedding and jointing and demonstrate that the site is adequate to accommodate the proposed spillway.

5.A.(6)(g) The following criteria shall be required, as a minimum in the geotechnical design:

1. The loading conditions shall not exceed the allowable stress of the foundation and appurtenant structures;

2. Seepage through the embankment, abutments, and the foundation shall be controlled to prevent internal erosion and external sloughing;

3. The embankment shall be protected against external erosion;

4. The crest width shall be equal to the vertical height plus freeboard in feet divided by 5 plus 10 feet. However, the maximum crest width required shall be 25 feet;

5. Minimum compacted densities for embankment materials shall be. 95 percent of maximum dry density for ASTM D-698 (Standard Proctor) or 90 percent for ASTM D1557 (Modified Proctor), as found in the 1986 "Annual Book of ASTM Standards", Section 04.08, Soil and Rock; Building Stones, 1916 Race Street, Philadelphia, Pennsylvania, 19103, which is hereby incorporated by reference into this rule, and does not include later amendments to, or editions of, the incorporated material. Impervious zones with clay fines shall be controlled using Standard Proctor criteria to maintain the plastic nature of the material; and

6. The minimum density for cohesionless materials shall be 70 percent relative density as determined by ASTM D-4253 and 4254 as found in the 1986 "Annual Book of ASTM Standards", Section 04.08, Soil and Rock; Building Stones, 1916 Race Street, Philadelphia, Pennsylvania, 19103, which is hereby incorporated by reference into this rule, and does not include later amendments to, or editions of, the incorporated material.

5.A.(6)(h) The methods and procedures for determining slopes outlined in the "Design of Small Dams", United States Department of the Interior, Bureau of Reclamation, Second Edition, 1973, 1977 revised reprint, U.S. Government Printing Office, Washington, D.C., 20402, which is hereby incorporated by reference into this rule, and does not include later amendments to, or editions of, the incorporated material, are acceptable for dams up to 50 feet high. For dams over 50 feet, stability analyses shall be conducted.

5.A.(6)(i) For earth dams, the minimum static stability factor of safety (FS) under steady state conditions is 1.5, the minimum FS for rapid drawdown is 1.2, and the minimum FS for dams requiring residual soil strength analysis shall be determined by the State Engineer.

5.A.(6)(j) For earth dams the seismic stability criteria shall be as follows:

5.A.(6)(j)(I) All Class I dams and Large and Intermediate size Class II dams shall be designed to at least with-stand the predicted earthquake loads, based upon an analysis of the potentially active faults, unless sufficient investigations indicate the faults are not active. Accelerations shall be determined by methods acceptable to the State Engineer.

5.A.(6)(j)(II) For all Class I dams, and Large and intermediate size Class II dams, the minimum seismic stability analysis required shall be a pseudo-static analysis which utilizes an appropriate pseudo-static load coefficient as defined in rule 5.A.(6)(j)(V) of not less than 0.05.

5.A.(6)(j)(III) All Class I dams, and Large and Intermediate size Class II dams, which have cohesionless materials in the embankment or foundation, shall be evaluated for liquefaction potential. If the evaluation indicates that the material in question is liquefiable under the design earthquake loading, the problem shall be remedied.

5.A.(6)(j)(IV) For all Class I dams, and Large and Intermediate size Class II dams, pseudo-static analysis shall be acceptable if all or the following conditions are satisfied:

1. The dam and foundation are not subject to liquefaction, as determined in Rule 5.A.(6)(j)(III);

2. The dam is a well-built (densely compacted) dam and predicted peak bedrock accelerations are 0.2g or less, or the dam is constructed of clay soils on a clay or rock foundation and predicted peak bedrock accelerations are 0.35g or less;

3. The static factors of safety of the critical failure surfaces involving the dam crest (other than the infinite slope case) are greater than 1.5, and

4. Freeboard is a minimum of three percent of the embankment height, but not less than three feet.

5.A.(6)(j)(V) The minimum acceptable pseudo-static stability analysis factor of safety is 1.0, and shall be attainable using a pseudo-static load coefficient of one-half the predicted peak bedrock acceleration (g's), but not less than 0.05.

5.A.(6)(j)(VI) For those Class I dams, and Large and Intermediate Class II dams, for which a pseudo-static analysis is not appropriate, as determined by Rule 5.A.(6)(j)(IV), a deformational analysis shall be performed in a manner acceptable to the State Engineer. The freeboard remaining due to deformation of the dam shall not be less than three feet.

5.A.(7) A design report which complies with these Rules and shall include information to evaluate the design of the dam and appurtenances including references and page numbers to support any assumptions used in the design. The design report should contain information to show that the following have been met:

5.A.(7)(a) Filter design for all chimney drains, filter blankets, and toe drains must be acceptable to the State Engineer. The use of geotextiles as a filter material is not allowed where the drains are not easily accessible for repair or where excavation of the drain can create an unsafe condition at the dam.

5.A.(7)(b) Underdrains and collection pipes shall be constructed using noncorrodible materials.

5.A.(7)(c) Rock riprap shall be well graded, durable and sized to withstand wave action, or channel velocities, and shall be placed on a well-graded pervious sand and gravel bedding or geotextile. Soil cement, designed and constructed in accordance with the principles defined in the "Design of Small Dams", United States Department of the Interior, Bureau of Reclamation, Second Edition, 1973, 1977 revised reprint, U.S. Government Printing Office, Washington, D.C., 20402, which is hereby incorporated by reference into this rule, and does not include later amendments to, or editions of, the incorporated material, may be used in lieu of rock riprap.

5.A.(7)(d) All outlet systems shall be designed and installed in a manner acceptable to the State Engineer and meet the following criteria:

5.A.(7)(d)(I) The outlets for Class I dams shall be capable of releasing the top five feet of the reservoir capacity in five days, and for all other classes of dams as required by the State Engineer. In addition, outlets shall be capable of passing inflow to the reservoir with a minimum of ten feet of head, in order to meet the demands of downstream senior water rights, and the owner's release requirements.

5.A.(7)(d)(II) All principal outlets connected to a pipeline shall have a by-pass valve which will meet the capacity criteria as defined in Rule 5.A.(7)(d)(I) above.

5.A.(7)(d)(III) Outlets for all dams, except for dams with ungated outlets, shall have an operating or guard gate installed at the upstream end of the conduit. Installations where the gates are located within the dam may not require guard gates if it is determined that the safety inspection of the dam will not require inspection of the outlet upstream from the gate, in accordance with criteria set forth in "ACER Technical Memorandum No. 6" USDI, Bureau of Reclamation, Denver, Colorado, November 1985, which is hereby incorporated by reference into this rule, and does not include later amendments to, or editions of, the incorporated material.

5.A.(7)(d)(IV) Outlets shall have trash racks unless exempted by the State Engineer for good cause shown.

5.A.(7)(d)(V) The design report shall include an outlet discharge table (in cubic feet per second) showing the discharge for 10 feet of head, and the discharge for each foot between an elevation five feet below the spillway crest and the crest of the dam. The equation(s) used for determining the discharge shall also be included.

5.A.(7)(e) All spillways shall be designed and installed in A manner acceptable to the State Engineer and meet the following criteria:

5.A.(7)(e)(I) The owner must safely conduct the spillway flows to the natural channel that would exist if the dam was not built. Where the spillway channel discharges into an adjacent basin different than the one on which the dam is located, the owner shall own or possess a right-of-way easement in the flood channel downstream to the location where the maximum discharge would no longer create additional significant damage.

5.A.(7)(e)(II) Log booms shall be installed in the spillway approach where logs and other debris may block spillway flow or damage the spillway structure.

5.A.(7)(e)(III) Emergency pipe spillways shall be designed and installed in a manner acceptable to the State Engineer.

5.a.(7)(e)(IV) For flood water detention dams, the principal spillway and outlet shall be able to pass all flood waters at a discharge rate as specified by the pertinent Division Engineer.

5.A.(7)(f) Dam site and reservoir area requirements are as follows:

5.A.(7)(f)(I) The design of a new reservoir or enlargement of an existing dam shall not result in the inundation of properties (except marina-type structures) during the Inflow Design Flood (IDF) unless the owner owns or obtains flood right-of-ways for all areas which may be inundated by the reservoir surcharge capacity. The owner shall submit a written statement certifying he is owner of the properties, or owns the right-of-way on all affected properties, or possesses a right-of-way easement for the reservoir inundation zone.

5.A.(7)(f)(II) The reservoir area shall be cleared of logs and debris unless waived by the State Engineer.

5.A.(7)(f)(III) Borrow areas shall not be located closer than 200 feet of either toe of the dam unless waived by the State Engineer for good cause shown.

5.A.(7)(f)(IV) The dam crest and appurtenant structures shall be accessible by equipment and vehicles for emergency operations and maintenance.

5.A.(7)(g) Concrete dams shall be designed in accordance with principles provided in U.S. Bureau of Reclamation publications "Design of Gravity Dams", 1976, and "Design of Arch Dams", 1977. Roller compacted concrete may be used in concrete construction in accordance with the state-of-the-art. The State Engineer may require additional analysis when the above cited references are inapplicable.

5.A.(8) An instrumentation plan which shall meet the following requirements:

5.A.(8)(a) Gage rods shall be installed in the proximity to the outlet on all dams. The zero mark of the gage shall be placed at the invert elevation of the entrance to the outlet. The gage shall be clearly marked in feet and tenths of feet, and extend to within one foot of the crest of the dam. If the Division Engineer so requires, the gage shall be marked in hundredths of a foot. The elevation of the reservoir may be measured by installing "gages" in the "wet well" of an outlet, but they shall be calibrated to the invert of the entrance to the outlet.

5.A.(8)(b) Class I and Class II dams shall have the following instrumentation:

5.A.(8)(b)(I) Gage rods as described in Rule 5.A.(8)(a) above;

5.A.(8)(b)(II) Monuments, which allow measurement of the horizontal and vertical movements of the dam, that are installed in a manner acceptable to the State Engineer;

5.A.(8)(b)(III) Weirs or flumes or other measuring devices installed in a manner acceptable to the State Engineer, which allow monitoring of leakage through the embankment or foundation;

5.A.(8)(b)(IV) Station markers at least every 100 feet along the crest of the dam; and

5.A.(8)(b)(V) Piezometers to allow monitoring of the phreatic surface within the dam installed in accordance with industry standards and in a manner acceptable to the State Engineer.

5.A.(8)(c) Class III dams shall have the following instrumentation:

5.A.(8)(c)(I) Gage rods as described in Rule 5.A.(8)(a) above; and

5.A.(8)(c)(II) Seepage weirs or flumes to allow monitoring of leakage through the embankment or foundation.

5.A.(8)(d) Class IV dams will not require instrumentation.

5.A.(9) A detailed cost estimate of the construction of the dam including the engineering fees. The cost estimate will remain confidential until after the construction contract is executed.

5.A.(10) A filing fee of $2.00 per $1,000 (or fraction thereof) of the cost estimate, limited to a maximum of $200.00. (See Rule 17.)

Rule 6. Requirements for Alteration, Modification, or Repair of an Existing Dam Which will Affect the Safety of the Structure.

Rule 6.A. An owner proposing to alter, modify, or repair a dam shall submit an application package in a form acceptable to the State Engineer and receive approval of the construction plans and specifications from the State Engineer prior to construction. The provisions of Rule 6 shall apply to such application only to the extent they directly relate to the activity for which approval is being sought.

6.A.(1) The requirements of Rule 5.A.(1), 5.A.(2), 5.A.(3), 5.A.(9), and 5.A.(10) shall apply except as modified by Rules 6.A.(2) and 6.A.(3). The requirements of Rules 5.A.(5) (Hydrology Report), 5.A.(6) (Geotechnical Report), 5.A.(7) (Design Report), 5.A.(8) (Instrumentation) apply only where they are needed to support the application.

6.A.(2) Plans for the repair of a dam, or alteration of Class I or Class II dams to nonjurisdictional size may be approved by the State Engineer by letter in lieu of the formal plans procedure per Rule 5.A.(2) and 5.A.(3) subject to the following conditions:

6.A.(2)(a) A completed application form provided by the State Engineer shall be submitted, accompanied by a plan for the repair or alteration and the appropriate specifications, which were prepared by an engineer. The provisions of Rules 5.A.(9), 5.A.(10) (cost estimate and fees) and Rule 11.B. (nonjurisdictional dams) shall apply.

6.A.(2)(b) The plans and specifications shall contain sufficient detail to enable a contractor to bid on, and construct the repair, or alter the dam. The provisions of Rule 9 (construction quality control), except for the time limits of Rules 9.A.(1), 9.B.(1), and 9.C.(1), and Rule 10 (acceptance of construction) shall apply. The engineer shall give as much notice of the start of construction as possible; and

6.A.(2)(c) Upon completion of a repair, the engineer shall file AS-CONSTRUCTED plans that are in conformance with Rules 5.A.(2) and 5.A.(3). (See Rule 11.B.)

6.A.(2)(d) AS-CONSTRUCTED plans are not required for alterations to nonjurisdictional size.

6.A.(3) Plans for the repair of a small or minor size Class III dam, or any Class IV dam; and plans for the alteration of any Class III or Class IV dam to nonjurisdictional size are exempt from the provisions of Rules 5A, 6, 9 AND 10 except as specified in Rule 6.A.(3)(a).

6.A.(3)(a) The dam owner must provide at least thirty days advanced written notice to the State Engineer. The written notice must contain the name of the dam, the location of the dam, the name of the owner, and a clear description of the work to be performed. If the State Engineer determines that plans and specifications prepared by an engineer are necessary for the repair, the owner will be notified within five working days of the receipt of the notice. The owner cannot begin construction until the plans and specifications are approved by the State Engineer. If plans and specifications are not required, the State Engineer will inform the dam owner of engineering and construction requirements, if any, and will perform construction inspections as he deems necessary. The dam owner must keep the State Engineer informed of the project status, and provide the State Engineer with "AS-CONSTRUCTED" drawings and specifications within sixty days following completion of the work. The "AS-CONSTRUCTED" drawings must be drawn on good quality paper with permanent ink (or equivalent), such that the drawings are reproducible, and suitable as a long lasting permanent record

6.A.(4) The inflow design flood (IDF) requirements for existing dams shall be determined in accordance with the principles of Rule 5.A.(5)(c) and (d), except those structures whose spillways were designed and approved in accordance with the methods published in the U.S. Department of the Interior, Bureau of Reclamation, "Design of Small Dams", Second Edition, 1973, shall be considered adequate for the classification (formerly referred to as hazard rating) for which they were designed. If the classification has changed, then the provisions of Rules 5.A.(5)(c) and (d) apply.

6.A.(4)(a) Whenever the methods of Rule 5.A.(5)(c) and (d) apply, the requirements for determining the spillway capacity are summarized in the following table. These requirements may be waived for good cause shown. Spillways designed in accordance with these rules will not be required to enlarge them due to subsequent revisions in PMP estimates, unless, in the opinion of the State Engineer, there is a substantial threat to public safety.

INFLOW DESIGN FLOOD REQUIREMENTS

Dam Class	I	II	III	IV
Dam Size				
Large	.75 PMP	.50 PMP	100 YR	50 YR
Intermediate	.75 PMP	.50 PMP	100 YR	50 YR
Small	.75 PMP	.50 PMP	100 YR	25 YR
Minor	.50 PMP	100 YR	50 YR	25 YR

6.A.(4)(a)(I) Existing Large, Intermediate, and Small Class I dams shall have spillways capable of passing, as a minimum, the IDF generated by 75 percent of the probable maximum precipitation, unless an incremental damage analysis demonstrates a lesser flood is applicable.

6.A.(4)(a)(II) Existing, Minor Class I dams, and Large, Intermediate, and Small Class II dams shall have spillways capable of passing as a minimum, the IDF generated by 50 percent of the probable maximum precipitation, unless an incremental damage analysis demonstrates a lesser flood is applicable.

6.A.(4)(a)(III) Existing Minor Class II dams, and Large, Intermediate, and Small Class III dams shall have spillways capable of passing the 100-year IDF as defined in Rule 5.A.(5)(d).

6.A.(4)(a)(IV) Existing Minor Class III, and Large and Intermediate Class IV dams shall have spillways capable of passing the 50-year IDF as defined in Rule 5.A.(5)(d).

6.A.(4)(a)(V) Existing Small and Minor Class IV dams shall have spillways capable of passing the 25-year IDF as defined by Rule 5.A.(5)(d).

6.A.(4)(a)(VI) The minimum size spillway for all existing Class I dams and Large, Intermediate, and Small Class II dams, for which an incremental damage analysis shows a smaller spillway is justifiable under Rule 5.A.(5)(c), is the 100-year flood as defined by Rule 5.A.(5)(d).

6.A.(4)(a)(VII) For dams whose spillway cannot pass the IDF as defined above, the engineer may, as an alternative, provide documentation that overtopping by floods which exceed the spillway capacity, will not cause failure of the dam.

6.A.(4)(b) The minimum freeboard requirements for an existing dam shall be based upon the maximum depth determined to either prevent overtopping by wave action, or which will pass the IDF, or a minimum of three feet, unless the State Engineer approves less for good cause shown.

Rule 7. Requirements for Removing or Breaching an Existing Dam

Rule 7.A. An owner proposing to Remove or Breach a dam shall submit an application package in a form acceptable to the State Engineer prior to commencing work. Plans for Removal or Breach of a dam shall meet the following requirements:

7.A.(1) A completed application form provided by the State Engineer.

7.A.(2) For Class I and Class II dams, A breach plan prepared by an engineer.

7.A.(2)(a) The dam shall be excavated down to the level of the natural ground, or as necessary in accordance with Rule 7.A.(2)(c), at the maximum section; and the breach shall be of sufficient width to pass the 100-year 24-hour flood at a depth of less than five feet. However, the maximum breach width shall be the total removal of the dam regardless of the flood magnitude;

7.A.(2)(b) The sides of the breach shall be excavated to a slope which is stable but not steeper than one horizontal to one vertical;

7.A.(2)(c) The breach shall be designed to control silt, which has previously been deposited on the reservoir bottom and the excavated material from the breach from washing downstream;

7.A.(2)(d) The reservoir shall be emptied in a controlled manner which will not endanger lives or damage downstream properties; and

7.A.(2)(e) The drawing(s) of the plan for the breach of a dam shall include the location, dimensions and lowest elevation of the breach.

7.A.(3) For Class III and Class IV dams the owner shall submit a written notice of intent to breach the dam to the State Engineer.

7.A.(3)(a) The State Engineer shall determine the size of the breach in accordance with the following: The bottom width of the breach shall be one-half the height of the dam but not less than ten feet; and the side slopes not steeper than one horizontal to one vertical. The breach shall be to original ground at the low point in the foundation of the dam and the excavated material shall not be placed in the stream channel.

Rule 8. <u>Approval for Construction, Enlargement, Alteration, Modification, or Repair Becomes Void After Five Years.</u>

If construction, alteration, or repair of a reservoir dam is not commenced within five years of approval of the application, the State Engineer's approval shall be void. The owner must resubmit the application and receive approval before commencing construction, and shall meet the requirements of the current rules and regulation.

Rule 9. Construction Quality Control (Jurisdictional Dams):

9.A. For Large, Intermediate, and Small, dams rated Class I, the owner shall provide an engineer experienced in dam design and construction, who shall be responsible for the following:

9.A.(1) Not less than 30 days prior to construction, the engineer must submit to the State Engineer a general plan for construction observation. The construction observation plan shall include:

9.A.(1)(a) The date of the start of construction;

9.A.(1)(b) Names and qualifications of the engineer and staff to be used on the project;

9.A.(1)(c) A construction observation schedule for the engineer and its staff;

9.A.(1)(d) For dams on rock foundations, a schedule for observations of the foundation by a geologist, or engineering geologist;

9.A.(1)(e) A schedule for inspection of the gate installation by the gate manufacturer or its representative unless waived by the State Engineer;

9.A.(1)(f) Identification of the firm that will conduct the construction material tests in the field; and

9.A.(1)(g) A schedule of the construction material tests.

9.A.(2) Within ten working days of receipt, the State Engineer shall provide his written comments and approval, or conditions for approval of the construction observation plan. Construction shall not commence without said approval.

9.A.(3) Subsequent to submitting the construction observation plan, but no later than one week prior to commencement of construction, a meeting shall be held between the engineer, State Engineer and the contractor. The contractor shall develop and thoroughly explain their construction control plan along with any anticipated construction difficulties. During this meeting, the means used to divert and care for the stream during construction will be identified by the contractor; and if reasonable, the plan will be approved by the State Engineer. The name of the contractors and any principals in charge shall be furnished to the State Engineer at the meeting.

9.A.(4) The engineer shall observe the construction of the dam. It is the engineer's responsibility to make frequent periodic visits to observe the progress and quality of the construction to determine whether the construction is proceeding in accordance with the approved plans and specifications. The engineer shall endeavor to prevent defects and deficiencies in the construction of the dam and appurtenant structures, and shall disapprove or reject work failing to conform to the approved plans and specifications.

9.A.(5) The engineer shall maintain a record of construction, which as a minimum, shall include:

9.A.(5)(a) Daily activity and progress reports;

9.A.(5)(b) All test results pertaining to construction;

9.A.(5)(c) Photographs sufficient to provide a record of foundation conditions and various stages of the construction through completion;

9.A.(5)(d) All geologic information obtained; and

9.A.(5)(e) Construction problems and remedies.

9.A.(6) A construction progress report summarizing the contents of 9.A.(5)(a), 9.A.(5)(b), and 9.A.(5)(e) above, must be submitted to the State Engineer every 30 days or more frequently if directed by the State Engineer. A summary report of all the items in Rule 9.A.(5) shall be submitted at the end of cosntruction.

9.A.(7) The engineer shall give the State Engineer at least five days advance notice of initial materials placement on the dam's foundation, in the cutoff trench, and on the outlet foundation (or any appurtenance requested by the State Engineer in advance), to allow observation by the State Engineer.

9.A.(8) When unforeseen site conditions or material availability require that the construction work differ significantly from the approved plans and specifications, a change order, including details, must be provided by the engineer to the State Engineer. No change shall be executed until approved by the State Engineer. Major changes must be submitted in writing with supporting documentation, and approved in writing by the State Engiener. Minor changes may be transmitted verbally by the engineer and approved by the State Engineer verbally.

9.A.(9) The engineer shall give the State Engineer at least 10 days advance written notice of the engineer's final construction inspection.

9.A.(10) The engineer shall notify the State Engineer of the completion of the construction in accordance with Rule 10.

9.B. For Minor, Class I Dams, and Large, Intermediate, and Small dams rated as Class II, the owner shall provide an engineer experienced in dam design and construction, who shall be responsible for the following:

9.B.(1) Not less than 30 days prior to construction or as soon as possible for dams whose construction season is affected by freezing weather, the engineer must notify the State Engineer in writing of the following:

9.B.(1)(a) The date of the start of construction;

9.B.(1)(b) The names and qualifications of the engineer and staff to be used on the project;

9.B.(1)(c) A schedule for construction observation by the engineer, including the foundation of the dam;

9.B.(1)(d) Identification of the firm that will conduct the construction material tests; and

9.B.(1)(e) A schedule of the construction material tests.

9.B.(2) The engineer shall observe the construction of the dam. It is the engineer's responsibility to make periodic visits to observe the progress and quality of the construction in order to determine whether the construction is proceeding in accordance with the approved plans and specifications. The engineer shall endeavor to guard against defects and deficiencies in the construction of the dam, and shall disapprove or reject the work failing to conform to the approved plans and specifications. Photographs of the progress of the construction shall be taken for the record.

9.B.(3) The engineer shall submit periodic reports as requested by the State Engineer and shall compile a record of all tests conducted, a summary of geologic information as related to the foundations, and any problems and remedies, for submittal at the end of construction.

9.B.(4) The engineer shall give the State Engineer at least five days advance notice to allow inspection of the cutoff trench and outlet foundation.

9.B.(5) Change orders shall be submitted in accordance with Rule 9.A.(8).

9.B.(6) The engineer shall give the State Engineer at least 10 days advance written notice of the engineers final construction inspection.

9.B.(7) The engineer shall notify the State Engineer of the completion of the construction in accordance with Rule 10.

9.C. For minor Class II and Large, Intermediate and Small dams rated as Class III, the owner shall provide an engineer experienced in dam design and construction, who shall be responsible for the following:

9.C.(1) Not less than 30 days prior to construction or as soon as possible for dams whose construction season is affected by freezing weather, the engineer shall notify the State Engineer in writing of the date construction will begin, the name of the engineer in charge of the project, and the name of the contractor;

9.C.(2) The engineer shall observe, or provide for the observation by a technician the construction work on the dam, the cutoff trench, and outlet works foundation to see that they are in substantial accordance with the approved plans. The engineer shall endeavor to guard against defects and deficiencies in the construction of the dam, and shall disapprove or reject work failing to conform to the approved plans and specifications;

9.C.(3) Periodic tests shall be taken and inspections made. Periodic progress reports shall be submitted as requested by the State Engineer. The engineer, shall compile a record of all tests conducted, and any problems and remedies, for submittal to the State Engineer at the end of construction;

9.C.(4) Change orders shall be submitted in accordance with Rule 9.A.(8);

9.C.(5) The engineer shall give the State Engineer at least 10 days advance written notice of the project engineers final construction inspection; and

9.C.(6) The engineer shall notify the State Engineer of the completion of construction in accordance with Rule 10.

Rule 9.D. For Minor, Class III dams and all Class IV dams, the owner shall provide an engineer experienced in dam design and construction who shall be responsible for the following:

9.D.(1) Notify the State Engineer of the start of construction;

9.D.(2) The engineer shall provide for the observation of the construction and endeavor to guard against defects and deficiencies in the construction of the dam and shall disapprove or reject work failing to conform to the approved plans and specifications;

9.D.(3) Change orders shall be submitted in accordance with Rule 9.A.(8);

9.D.(4) The engineer shall give the State Engineer at least 10 days advance notice of their final construction inspection; and

9.D.(5) The engineer shall notify the State Engineer of the completion of the construction in accordance with Rule 10.

Rule 10. Acceptance of Construction, Enlargement, Alteration, Modification or Repair (Jurisdictional Dams):

10.A. Construction for which application has been made pursuant to Rule 5 or Rule 6 shall not be deemed complete nor shall storage of water be permitted until the State Engineer furnishes to the owner a written statement of acceptance, unless temporary approval of storage is granted by the State Engineer. The acceptance shall specify the vertical height, freeboard, length of the dam, the capacity of the reservoir in acre-feet, and any limitation upon, or requirements for the use of the dam. The State Engineer shall furnish the acceptance or denial within 60 days of receipt of a complete notification of completion.

10.B. The engineer shall provide written notification of completion which shall include the following in order to be deemed complete:

10.B.(1) A written notification that the project is complete and in general conforms with the approved plans, specifications and change orders.

10.B.(2) The As-Constructed Plans which meet the requirements of Rule 5.

10.B.(3) A final construction report containing the following information, if applicable in accordance with the requirements of Rule 9:

10.B.(3)(a) A summary of construction, problems encountered, and solutions implemented to resolve the problems; and,

10.B.(3)(b) A summary of construction material tests and geologic observations; and,

10.B.(3)(c) Photographs of construction if required, from exposure of the foundation to completion of construction; and,

10.B.(4) A record of the location of permanent monuments and instrumentation as well as initial surveys and readings shall be submitted if applicable.

10.B.(5) A schedule for the first filling of the reservoir, specifying fill rates, water level elevations to be held for observation, and a schedule for inspecting and monitoring the dam. No filling schedule is required for minor dams rated Class III and all Class IV dams or if waived by the State Engineer for good cause shown. The owner, however, shall monitor the dam frequently during the first filling.

10.B.(6) A long-term instrumentation monitoring plan for new dams and enlargements (except for minor Class III and all Class IV dams) which shall include:

10.B.(6)(a) The frequency of monitoring;

10.B.(6)(b) The data recording format;

10.B.(6)(c) A graphical presentation of data; and,

10.B.(6)(d) The parties who will perform the work.

10.B.(7) The engineer shall provide periodic review of the data included in the long-term monitoring plan on at least an annual basis for the first five years, whereupon the monitoring shall continue in accordance with Rule 15.C.(2) and 15.C.(3). The engineer shall submit the data and a written assessment of the dam's performance to the State Engineer annually.

10.B.(8) An Emergency Preparedness Plan which conforms to Rule 16.

10.B.(9) Upon written request by the owner and for good cause shown, the State Engineer may temporarily approve storage of water prior to full compliance with Rule 10B. The written request shall include a schedule for compliance with Rule 10B.

Rule 11. <u>Nonjurisdictional Dams: Notification of Intent to Construct, Safety Requirements, and Breach Requirements</u>:

Rule 11.A. Any person intending to construct a nonjurisdictional dam which does not meet the requirements for a Livestock Water Tank or Erosion Control Dam, must submit notice of the intent to construct a dam on forms provided by the State Engineer not less than 10 days prior to construction. (See Section 37-87-125, C.R.S. [1985 Supp.].) The forms shall be submitted to the Division Engineer of the Water Division in which the dam is to be located.

Rule 11.A.(1) This rule does not apply to exempt structures as defined under Rule 18 of these regulations.

Rule 11.A.(2) Any owner violating the provisions of this rule shall drain the reservoir and prevent the storage of water in the reservoir upon the order of the Division Engineer; additionally, any dam constructed in violation of the provisions of this rule may be considered an obstruction and is subject to removal pursuant to Section 37-92-502(7), C.R.S. (1973).

Rule 11.B. Jurisdictional dams which will be altered to nonjurisdictional size shall meet the following safety requirements:

Rule 11.B.(1) Dams which are rated Class I or Class II before they have been altered shall require that their plans be submitted for approval in accordance with Rule 6. The spillway shall be capable of passing as a minimum a 25-year 24-hour precipitation flood or 25-year snowmelt flood, whichever is greater, with no residual freeboard, and without serious damage to the spillway or dam. Freeboard shall be at least three feet but not greater than required to pass the 25-year flood, and pipe spillways shall be at least 30 inches in diameter if approved by the State Engineer.

Rule 11.B.(2) Dams which are rated Class III before they have been altered shall require that their owner submit written notice of the intent to alter the dam to the State Engineer. The State Engineer will advise the owner of what requirements must be met. Pipe spillways shall be at least 30 inches in diameter if approved by the State Engineer, and capable of passing a 10-year 24-hour precipitation flood or 10-year snowmelt flood, whichever is greater, with no residual freeboard and installed at sufficient depth to make the dam nonjurisdictional. Freeboard requirements will be determined by the State Engineer.

Rule 11.C. Existing nonjurisdictional dams shall meet the following requirements:

Rule 11.C.(1) Dams which are Class I or Class II structures, and which are found to be unsafe for storage by the State Engineer, shall have the plans for their repair prepared by an engineer and submitted to the State Engineer for approval before construction. The plans do not need to meet the requirements of Rule 5, but must be of sufficient detail to provide for the quality control of the work. Spillways, freeboard, and pipe spillways shall meet the requirements of Rule 11.B.(1).

Rule 11.C.(2) Dams which are Class III, and are found to be unsafe for storage by the State Engineer, shall be repaired in accordance with the State Engineer's directions. Spillways, freeboard, and pipe spillways shall meet the requirements of Rule 11.B.(2).

Rule 11.D. Dams which have been altered to nonjurisdictional size, and existing nonjurisdictional dams which are Class IV, or are found to be nonhazardous by the State Engineer, shall have spillways that will control the level of the reservoir and should be able to pass normal runoff in a manner acceptable to the State Engineer.

Rule 11.E. Owners who intend to breach their nonjurisdictional dams shall submit written notice to the State Engineer. The breach shall have a minimum bottom width of ten feet and at least 1:1 side slopes. The breach shall be to original ground, at the low point in the foundation of the dam. Excavated material shall not be placed in the stream channel.

Rule 12. <u>General Maintenance, Ordinary Repairs, and Emergency Actions Which Do Not Require Prior Approval of the State Engineer</u>:

12.A. General maintenance and ordinary repairs which do not require prior approval of the State Engineer for the purpose of this rule shall be those activities which do not impair the safety of the dam. These activities include:

12.A.(1) Removal of brush or tall weeds.

12.A.(2) Cutting of trees and removal of slash from the embankment or spillway. Removal of small stumps is acceptable provided no excavation into the embankment occurs.

12.A.(3) Rodent control or extermination by trapping, poisoning, or shooting. Repair of minor rodent damage is acceptable provided it does not involve excavation into the embankment.

12.A.(4) Repair of erosion gullies on the embankment or in the spillway. Large gullies which have already weakened the dam must be repaired in accordance with Rule 6.

12.A.(5) Surface grading of the embankment crest or spillway to eliminate potholes and provide proper drainage provided that the freeboard is not reduced.

12.A.(6) Placement of additional riprap and bedding on the upstream slope, or in the spillway in areas which have sustained minor damage. This would involve restoring the original riprap protection where the damage has not yet resulted in weakening of the dam.

12.A.(7) Painting, caulking, or lubricating metal structures.

12.A.(8) Patching or caulking spalled or cracked concrete to prevent deterioration.

12.A.(9) Removing debris, rock, or earth from outlet conduits or spillway channels.

12.A.(10) Patching to prevent deterioration within outlet works.

12.A.(11) Replacement of worn or damaged parts of outlet valves or controls to restore them to original or equivalent condition.

12.A.(12) Repair or replacement of fences intended to keep traffic or livestock off the dam or spillway.

12.A.(13) And work of a similar nature and magnitude which does not impair the safety of the dam.

12.B. General maintenance and ordinary repair which may impair safety such as excavation into or near the toe of the dam, construction of new appurtenant structures for the dam, and repair of damage which has already significantly weakened the dam must be done in accordance with Rule 6. When questions arise concerning this rule, the determination of general maintenance and ordinary repair will be made by the State Engineer.

12.C. Emergency actions not impairing the safety of the dam may be taken before guidance can be provided by an engineer, and do not require prior approval of the State Engineer. Emergency actions will usually not serve as a permanent solution to the problem being addressed. Emergency actions may include:

12.C.(1) Stockpiling materials such as riprap, earthfill, sand, sandbags and plastic sheeting.

12.C.(2) Lowering the reservoir level by making releases through the outlet or a gated spillway, by pumping, or by siphoning. Where large releases are to be made, the Division Engineer shall be notified.

12.C.(3) Armoring eroded areas by placing sandbags, riprap, plastic sheeting, or other available material.

12.C.(4) Plugging leakage entrances on the upstream slope.

12.C.(5) Increasing freeboard by placing sandbags or temporary earthfill on the dam.

12.C.(6) Diverting flood waters to prevent them from entering the reservoir basin.

12.C.(7) Constructing training berms to control flood waters.

12.C.(8) Placing sandbag ring dikes around boils at the downstream toe to provide back pressure.

12.C.(9) Removing obstructions from outlet or spillway flow areas.

12.D. Lowering the water level by excavating the spillway or embankment is prohibited unless failure is imminent. The State Engineer shall be notified as soon as reasonably possible of any emergency condition that exists and any emergency action taken.

12.E. For all Class I and Class II dams, the Emergency Preparedness Plan must be implemented in conjunction with any emergency actions taken in accordance with Rule 12.D.

Rule 13. <u>Safe Storage Level</u>:

13.A. The State Engineer has the authority to determine the safe storage level for every reservoir in the state. The reservoir owner shall not store water in excess of the amount so determined by the State Engineer to be safe. The owner shall not place flashboards or other devices in the emergency spillway without first filing and receiving approval of an application for modification of the dam in accordance with Rule 6.

13.B. If the dam safety inspection or information from other reliable sources reveals problems affecting the safe storage level of the reservoir, the State Engineer will issue a restriction order. The dam owner shall comply with the restriction order. If the dam owner wishes to store water in his reservoir in excess of the level set in the restriction order, he shall provide for engineering evaluations deemed necessary by the State Engineer and shall complete required repairs.

13.C. When a determination of safe storage level is made by the State Engineer the safety evaluation flood for existing dams will be evaluated in accordance with the standards set forth in Rule 6.A.(4).

13.D. When a determination of safe storage level is made, the State Engineer will periodically review the classification of existing dams by evaluating the consequences of failure and applying the definitions of Rule 4.A.(5). If the State Engineer's review indicates that the consequences of failure have increased or decreased due to changes in development within the dam failure inundation area, the State Engineer will assign an appropriate new classification and will require within a reasonable time, that the dam meet the requirements of these rules as they apply to that classification.

Rule 14. <u>Safety Inspections by Owner's Engineer</u>:

14.A. An owner may provide a safety inspection report to the State Engineer regarding the safe storage level of a reservoir. The State Engineer may utilize the owner's safety inspection report in lieu of a State Engineer safety inspection report if said report is written by a qualified engineer, as defined below. The owner's engineer must notify the State Engineer and submit a written summary of qualifications at least 14 days prior to the scheduled safety inspection.

14.B. An engineer shall be considered qualified to provide information to the State Engineer regarding the safe storage level of a reservoir if the engineer meets the following minimum qualifications:

14.B.(1) Registration as a professional engineer in Colorado;.

14.B.(2) Three years of experience in the field of dam safety; and

14.B.(3) Actual experience in conducting safety inspections of dams.

14.C. Dam safety inspections by the owner's engineer shall include, but are not limited to: review of previous inspections, reports and drawings; site inspection of the dam, spillways, outlet facilities, seepage control and measurement system; and permanent monument or monitoring installations, if any. The inspection shall include an assessment of all parts of the dam which are related to the dam's safety. (See Rule 15. for outlet inspection requirements.) The engineer shall prepare an inspection report which describes the findings, and lists actions the dam owner must take to improve the safety of the dam to an acceptable level. The report shall include the engineer's recommendation of the safe storage level.

14.D. If the owner elects to retain an engineer to conduct safety inspections, such inspections shall be conducted annually for all Class I and Class II dams and once every five years for all Class III dams. Class IV dams will not be inspected periodically, but will be if a complaint is received about their safety.

Rule 15. <u>Owner's Responsibilities</u>:

15.A. It is the owner's responsibility to allow or to provide for inspection of outlet facilities on his dam. The frequency of outlet inspections and the requirements of those inspections are as follows:

15.A.(1) Class I and Class II dams shall receive a Type A outlet inspection annually, and Type B inspections not to exceed once every ten years unless the condition indicates more frequent inspections are necessary. A Type B inspection of the entire outlet conduit shall only be required on dams without upstream gates if ordered by the State Engineer in conformity with Rule 15.A.(4). Type B inspections may be waived where the condition of the outlet conduit would not be considered detrimental to the safety of the dam.

15.A.(2) Class III and Class IV dams shall receive a Type A outlet inspection in conjunction with the safety inspection of the dam.

15.A.(3) A Type A outlet inspection shall consist of:

15.A.(3)(a) Observation of exposed surfaces of the inlet and outfall structures, and control valves and vaults;

15.A.(3)(b) Testing of the outlet valves for proper operation;

15.A.(3)(c) Observation of the downstream end of the conduit and adjacent embankment for leakage; and,

15.A.(3)(d) Observation of the dam (upstream slope, crest, downstream slope or natural ground) in the vicinity of the outlet alignment for signs of distress which would indicate failure of the outlet system.

15.A.(4) A Type B outlet inspection shall consist of a complete Type A inspection, a close inspection of the interior of the conduits, outlet wells, and access ways, and testing of the outlet valve(s) throughout the full operating range. In cases where the conduits are too small for a person to safely enter, the owner shall provide for an inspection using video or other remote sensing equipment capable of detecting flaws or imperfections within the conduit. A written report of inspection findings, including the opinion of the owner's engineer, must be submitted to the State Engineer unless waived by the State Engineer for good cause. A Type B inspection of the normally inundated outlet conduit of a dam without upstream guard gates shall be requried only when existing baseline data available to the State Engineer is inadequate to permit an evaluation of the condition of the outlet conduit. Thereafter, such inspections shall only be required if the criteria set forth in ACER Technical Memorandum No. 6. U.S. Department of the Interior, Bureau of Reclamation, 1985, indicate the need for an inspection. In ordering such inspections, the State Engineer shall coordinate with the dam owner and make all reasonable efforts to prevent expense and waste of water consistent with ensuring dam safety.

15.A.(5) At any time the water level in a dam without upstream gates on the outlet conduit will be lowered to the invert of the conduit, or the normally inundated conduit will be otherwise dewatered and available for inspection, the dam owner shall inform the State Engineer in writing and may request the State Engineer to conduct an inspection of the entire outlet conduit for the purposes of this rule. If, upon ten days notice of the opportunity to inspect the outlet conduit, the State Engineer fails to do so, he shall not thereafter require an inspection of the conduit in absence of a finding that an inspection is required made in accordance with ACER Technical Memorandum No. 6.

15.B. The owner is responsible for ensuring frequent observation of his dam, unless prohibited by weather or difficulty of access to the dam, especially at times when the reservoir is full, during heavy rains or flooding, and following an earthquake. When the reservoir water level is greater than half the full storage capacity, Class I and Class II dams shall be observed at least twice a month, and a Class III dam shall be observed at least every three months. The observations shall be conducted in accordance with methods acceptable to the State Engineer. Conditions which threaten the safety of the dam must be reported to the State Engineer in accordance with the Emergency Preparedness Plan for Class I and II dams as soon as reasonably possible, after discovery of the conditions. If dam failure appears imminent, the county sheriff (or emergency official) must be promptly notified. The owner is responsible for the safety of the dam and shall take action to lower the reservoir if it appears that the dam has weakened or is in danger of failing.

15.C. The owner of a dam is responsible for installing, maintaining, and monitoring the required instrumentation:

15.C.(1) The following minimum instrumentation is required on existing dams; however, the State Engineer may require additional instrumentation when he deems it necessary.

15.C.(1)(a) Class I Dams shall have monuments to allow monitoring of horizontal and vertical movement of the embankment, and weirs or flumes to allow monitoring of leakage.

15.C.(1)(b) Class II and Class III Dams shall have weirs or flumes to allow monitoring of leakage.

15.C.(1)(c) All dams shall have gage rods or other acceptable measuring device pursuant to Rule 5.A.(8)(a).

15.C.(2)The dam owner shall monitor weirs during each routine observation of the dam (see Rule 15.B.). Owners of Class I dams shall also be responsible for providing second order surveys of horizontal and vertical monuments. These surveys are required annually for five years (including the year of installation of the monuments), and then once every five years thereafter. The State Engineer may also approve other methods for monitoring of movement monuments on the dam and may require monitoring at any frequency deemed necessary based upon review of inspection data and information from other reliable sources.

15.C.(3) The dam owner is responsible for ensuring that all instrumentation data is properly recorded in an acceptable format and sent to the State Engineer annually. The State Engineer may require that instrumentation data for Class I and Class II dams be evaluated by the owner's engineer and the analysis sent to the State Engineer annually, unless more frequent reporting is required by the State Engineer.

15.C.(4) The dam owner shall promptly notify the State Engineer of any abnormal changes in instrumentation data, as compared to historical data and trends.

15.D. The owner is responsible for adequate and timely maintenance of the dam. The owner shall establish an annual maintenance plan to ensure that the maintenance, as identified in Rule 12.A., is accomplished.

15.E. The owner shall ensure that trash racks are installed on all outlet structures unless waived in writing by the State Engineer.

15.F. Any change in ownership of a dam shall be immediately filed with the Office of the State Engineer.

Rule 16. Emergency Preparedness Plans (EPP):

16.A. Owners of Class I and Class II dams shall prepare, maintain, and exercise Emergency Preparedness Plans (EPP) for immediate defensive action to prevent failure of the dam. An EPP shall contain as a minimum the following:

16.A.(1) The identification of equipment, manpower, and material available for implementation of the plan;

16.A.(2) A notification procedure for informing the local emergency agencies (e.g., emergency coordinator or county sheriff), and the State Engineer of the problem;

16.A.(3) A dam failure inundation map for Class I dams;

16.A.(4) A topographic map for Class II dams showing the stream which will be flooded; and,

16.A.(5) A procedure for warning nearby local residents if failure of the dam is imminent.

16.B. The owner shall use the State Engineer's model EPP, which is available at no cost, or equivalent, for guidance in preparing the details of the components above.

16.C. The owner shall submit a copy of the proposed EPP to the Colorado Division of Disaster Emergency Services (DODES) and all local emergency coordinators involved in the plan for review. The owner shall incorporate reasonable recommendations from the above, if received within sixty days of the submittal.

16.D. The owner shall review and update the EPP as necessary annually.

Rule 17. Fees:

17.A. The owner shall submit with the application for construction, enlargement, alteration, modification, or repair an amount equal to two dollars for each one thousand dollars or fraction thereof of the estimated cost of construction including engineering costs, but the maximum fee shall not exceed $200. When an owner resubmits an application which was previously received and disapproved by the State Engineer, the owner shall submit a new filing fee in accordance with the above. Checks shall be made payable to the Colorado Division of Water Resources.

17.B. Pursuant to Sections 37-87-106 and 111, C.R.S. (1973)(1987 Supp.), the dam owner shall be responsible for payment of invoices from the State Engineer for safety inspections and construction observation. The invoice shall include actual salary, travel, subsistence, and itemized extraordinary expenses at prevailing rates for state officers and employees not to exceed $125 per day per dam or reservoir. The total charge to one owner shall not exceed $125.00 per day. The payment is due within 30 days of receipt of the invoice.

Rule 18. Exempt Structures:

18.A. Existing or proposed structures not designed or operated for the purpose of impounding water are exempt from these rules and regulations. Exempt structures include:

18.A.(1) Highways, roadfills, and railroad embankments, (except those designed or modified with the purpose or effect of impounding water for uses other than flood detention); and,

18.A.(2) Diversion dams if less than jurisdictional size, and all diversion dams of any size if Class III or IV.

18.A.(3) Refuse embankments; (e.g., solid waste disposal facilities).

18.B. Mill tailing impoundments which are permitted under the Colorado Mined Reclamation Act, Sections 34-32-101 through 125, C.R.S. (1973)(1987 Supp.)(Minerals), or the Colorado Surface Coal Mining Reclamation Act, Sections 34-33-101 through 137, C.R.S. (1973)(1987 Supp.) (Coal) are exempt from these rules and regulations.

18.B.(1) Any solution process impoundment permitted under the Colorado Mined Reclamation Act, or the Colorado Surface Coal Mining Reclamation Act, are exempt from these regulations.

18.C. Uranium mill tailing and liquid impoundment dams, permitted under the Colorado Department of Health are exempt from these rules and regulations. Raw and potable water dams, sewage effluent dams, and water treatment sludge dams associated with the uranium mill are not exempt.

18.D. Siltation structures which are permitted under the Colorado Surface Coal Mining Reclamation Act, Sections 34-33-101 through 137, C.R.S. (1973)(1987 Supp.)(Coal), are exempt from these rules and regulations.

18.E. Structures which store water only below the lowest point of the natural ground are exempt from these rules and regulations, unless an outlet works is constructed to develop water.

18.F. Livestock Water Tanks as defined in the Livestock Water Tank Act of Colorado, Sections 35-49-101 through 116, C.R.S. (1973), are exempt from these rules and regulations.

18.G. Erosion Control Dams as defined in Section 37-87-122, C.R.S. (1973), are exempt from these rules and regulations.

Rule 19. Restriction of Recreational Facilities Within Reservoirs:

19.A. No person, including any state or federal agency, quasi-municipal corporation, or political subdivision, shall construct any permanent recreational structure within a reservoir below the elevation of the bottom of the spillway unless:

1. The facility is constructed to withstand partial or complete inundation without significant damage; or
2. The facility is necessary to the operation of the reservoir; and
3. The facility is capable of being restored with a minimum amount of cleaning or expense. Boatramps, docks, and marinas are exempt from these rules.

19.B. This rule does not apply to facilities completed prior to July 1, 1984, but shall apply to any enlargements or modifying of such facilities.

19.C. Any person planning on constructing, enlarging, or modifying any facility coming under this rule shall notify the State Engineer in writing 180 days in advance of construction. They shall include the following information:

1. The name and location of the reservoir and/or dam;

2. Whether the recreational facility is new, or an enlargement or modifying of a facility completed prior to July 1, 1984;

3. A description of the facility, its intended purpose, and its location within the reservoir including depth below the high water line; and

4. A description of how the facility will be able to withstand the damage from the inundation without a significant amount of cleaning or expense to restore it.

19.D. No person shall be allowed to construct, enlarge, or modify any facility coming under this rule until approved by the State Engineer.

Rule 20. Waiver or Delay of Enforcement of Rules by the State Engineer

The State Engineer may waive or delay the enforcement of any of the responsibilities of dam owners under the foregoing rules in particular cases if in his judgement dam safety will not be unreasonably impaired and the circumstances of the individual case so warrants. Such circumstances may include, but are not limited to, the benefits which would be realized by full enforcement, the cost or difficulty of complete compliance, the owner's good faith efforts to comply, the expected remaining life of the structure, and the impacts of beneficial use of water in Colorado.

Rule 21. Rules by Reference

Certified copies of the complete text of the materials incorporated by reference in these rules shall be maintained by the Office of the State Engineer and shall be available for public inspection during regular business hours. Certified copies of the material incorporated shall be provided at cost upon request. The title and address of the branch of the Office of the State Engineer which will provide information regarding how incorporated material may be examined or obtained is: Dam Safety Branch, 1313 Sherman Street, Room 818, Denver, Colorado, 80203.

Rule 22. Severability

If any portion of these Rules and Regulations for Dam Safety and Dam Construction is found to be invalid, the remaining portion of the rules shall remain in force.

Rule 23. Revision

The State Engineer may revise these Rules and Regulations for Dam Safety and Dam Construction in accordance with Section 24-4-103, C.R.S. Such revisions may be the result of new data or technology, or the submittal of a petition by an interested person pursuant to Section 24-4-103(7), C.R.S. and 2 C.C.R. 402-5 1.1.3.B.2.

Rule 24. Statement of Basis and Purpose Incorporated by Reference

The Statement of Basis and Purpose for the adoption of Rules and Regulations for Dam Safety and Dam Construction is incorporated by reference as part of these rules.

Rule 25. Effective Date

These rules shall become effective on September 30, 1988.

6883I

Rod Stude
Sales Engineer

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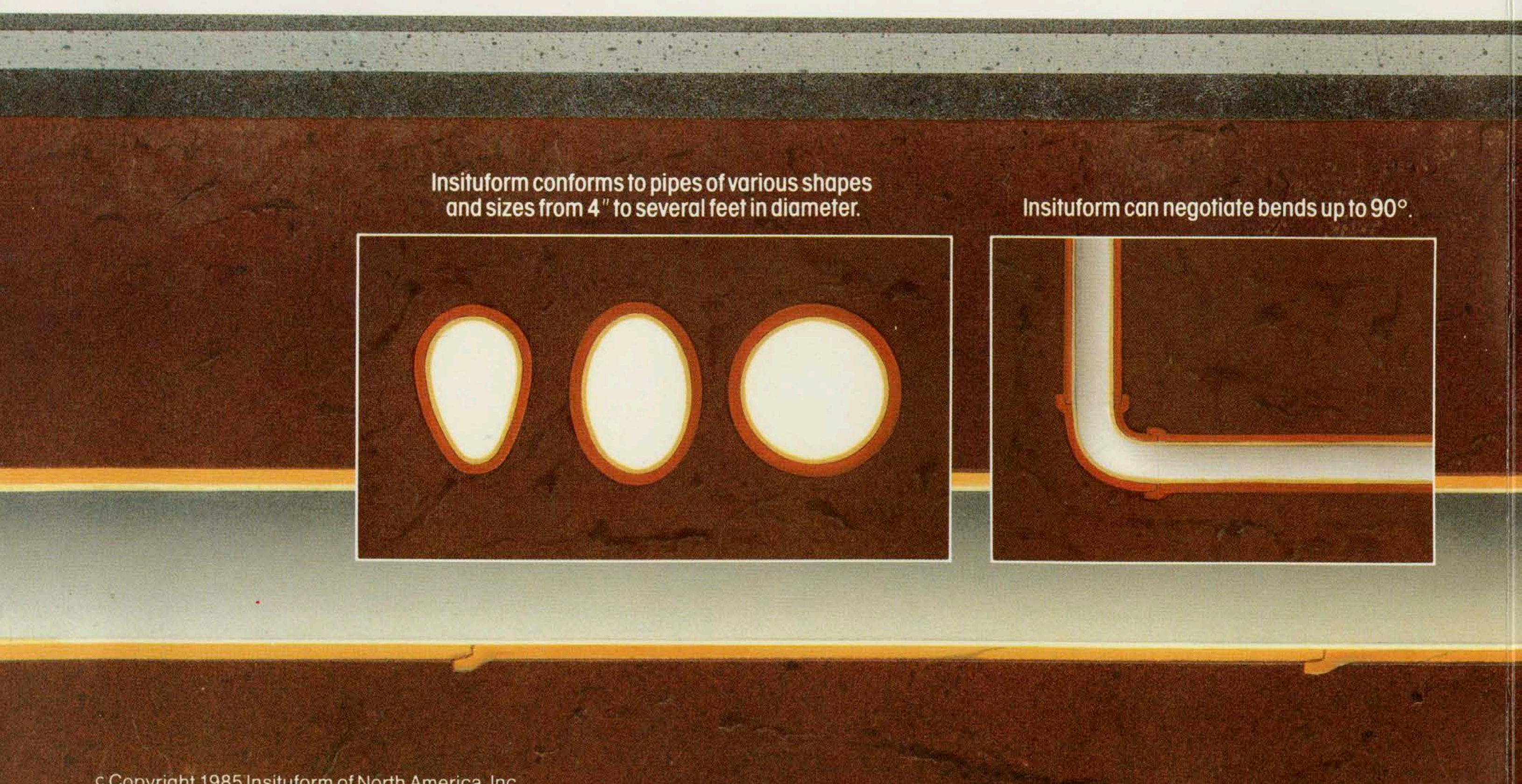
Why clients choose Insituform

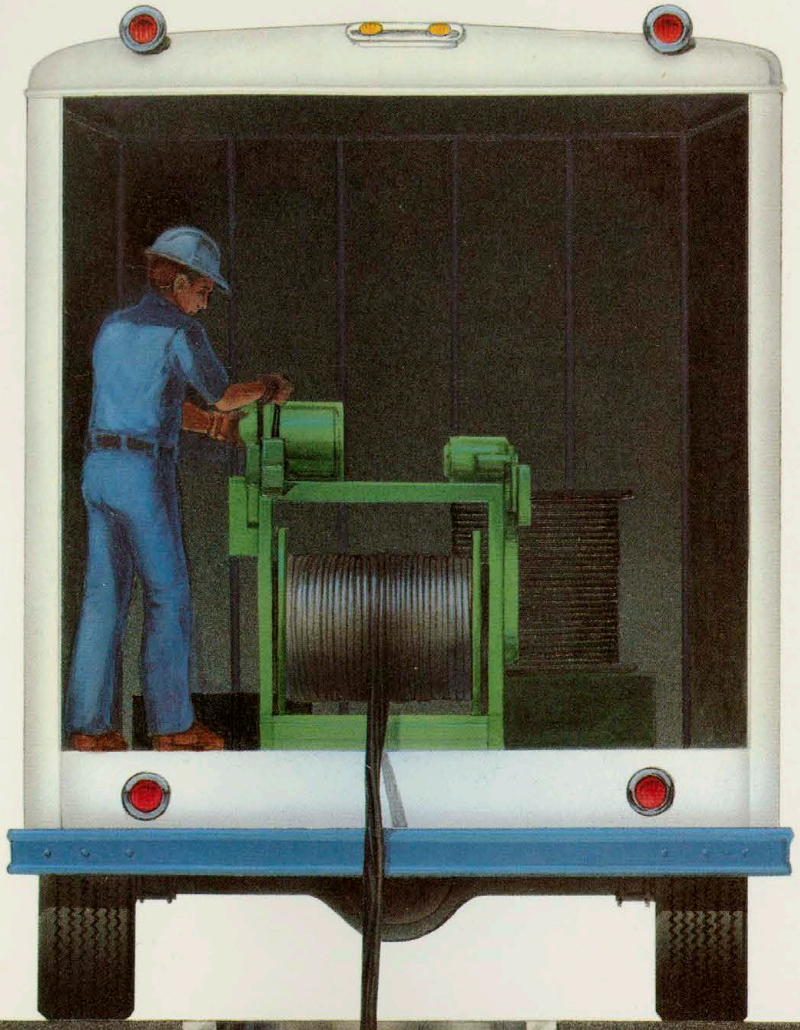
Mayors and City Managers from cities of all sizes and in all parts of the country tell us they choose Insituform for three big reasons. First, there's little, if any, disturbance to people or property. This means no torn-up streets, re-routed traffic, or complaints from irate homeowners and disgruntled businesses. Second, an Insituform installation may be accomplished in hours or days, while other methods can drag on for months or even years. And finally, they like the fiscal soundness of Insituform. When time, convenience, ease of installation, durability and performance are measured, Insituform is the obvious solution.

City Engineers also agree that Insituform is the Sensible Solution to pipe problems of all kinds. With Insituform, they know they'll be spared the hassles of excavation and the headaches of a long drawn-out project. Also, they won't have to tie up manpower for months and neither will they have to worry about pipe patching and maintenance in a few years. An Insituform pipe has no joints or seams to create future problems.



Insituform conforms to pipes of various shapes and sizes from 4" to several feet in diameter.

Insituform can negotiate bends up to 90°.



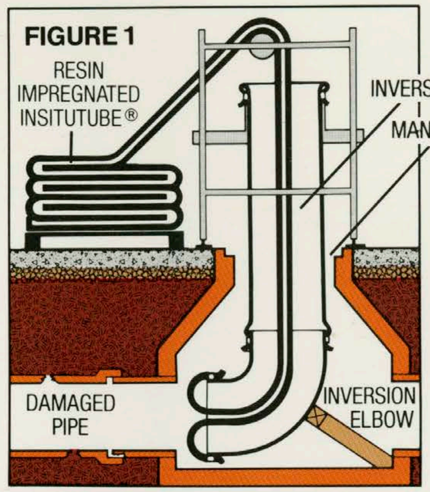
Industrial Engineers are also sold on Insituform. Since most plants can't afford to be down for more than a few hours at a time, Industrial Engineers are turning to Insituform for pipe replacement. Insituform can replace a damaged pipe overnight, over a weekend, or over a holiday to hold downtime to a minimum. And since an Insituform pipe is resistant to a wide variety of chemicals, it won't have to be replaced every few years. Industrial Engineers also like the fact that Insituform usually increases flow volume. The pipe's slick-as-glass interior offers little resistance and eliminates infiltration/exfiltration.

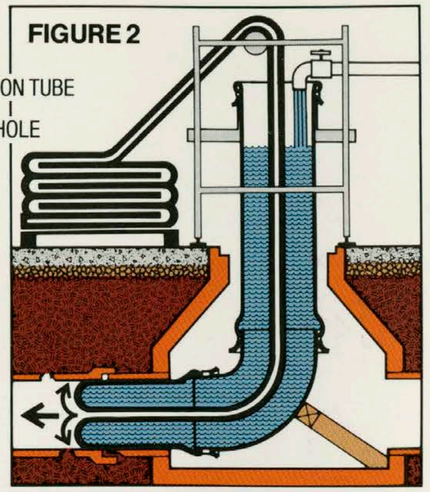
How Insituform is installed

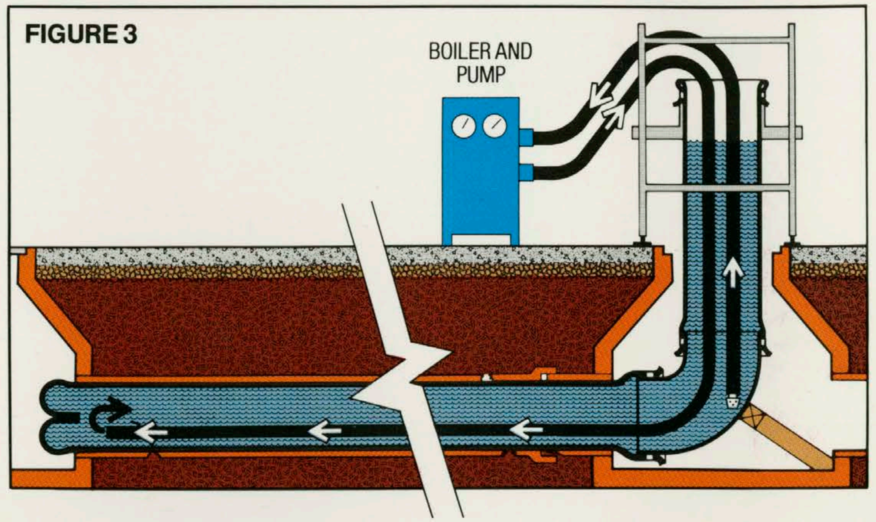
Figure 1. A special needled felt reconstruction tube (Insitutube), coated on the outside, is custom engineered and manufactured to fit the damaged pipe exactly. It is impregnated with a liquid thermosetting resin and lowered into a manhole through an inversion tube. One end of the Insitutube is firmly attached to the lower end of the inversion tube elbow.

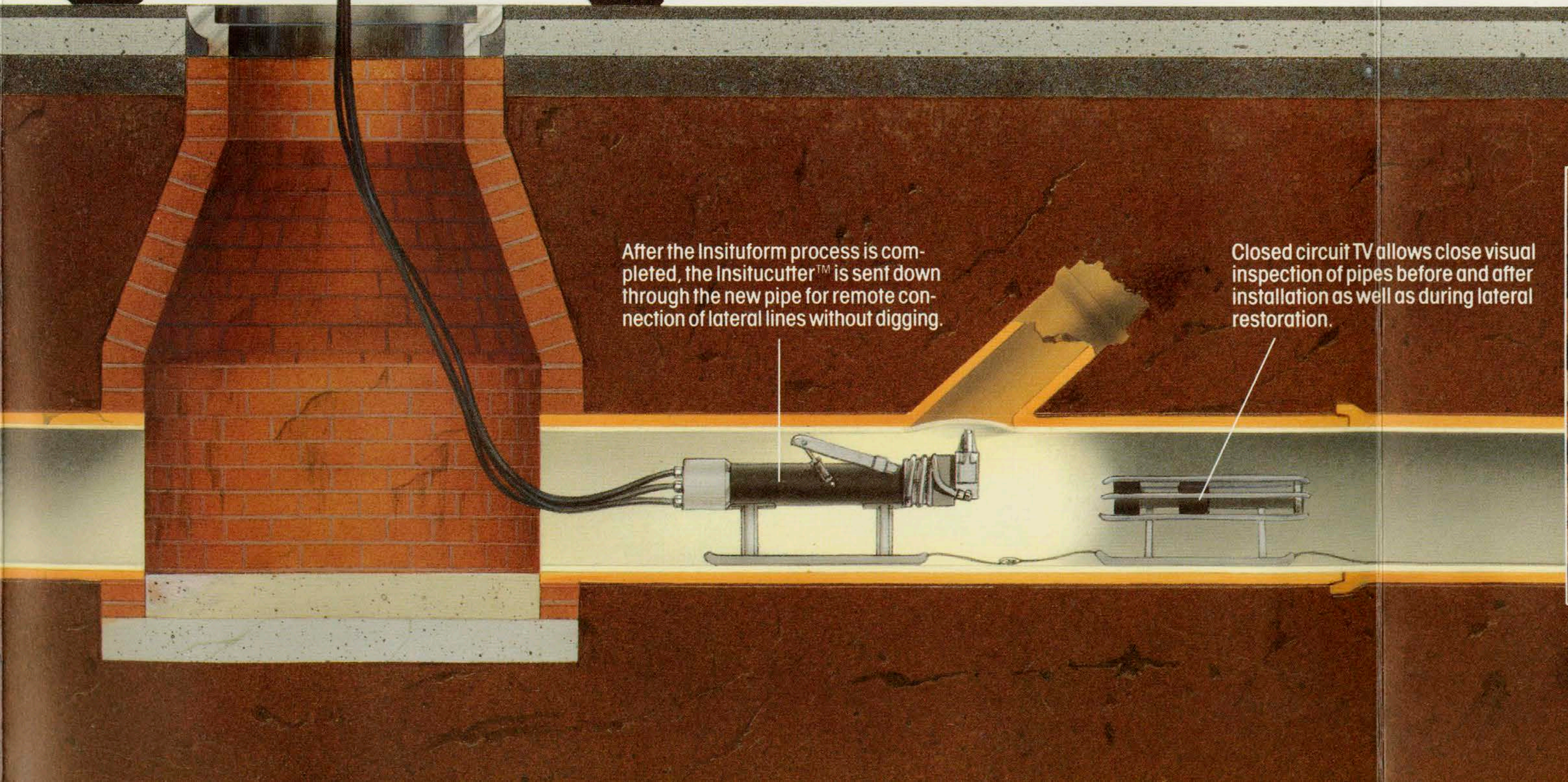
Figure 2. The inversion tube is then filled with water. The weight of the water pushes the Insitutube into the damaged pipe and turns it inside out, while pressing the resin impregnated side firmly against the inside walls of the old pipe. The smooth coated side of the Insitutube becomes the new interior surface of the pipe.

Figure 3. After the Insitutube is inverted through the old pipe to the desired length, the water is circulated through a boiler. The hot water causes the thermosetting resin to cure within a few hours, changing the pliable Insitutube into a hard, structurally sound, pipe-within-a-pipe (Insitupipe™). It has no joints or seams and is usually stronger than the pipe it replaced. The ends are cut off and the inversion tube and scaffolding are removed. Normally, there are no messy excavation repairs to be made since most work is done without digging or disruption.

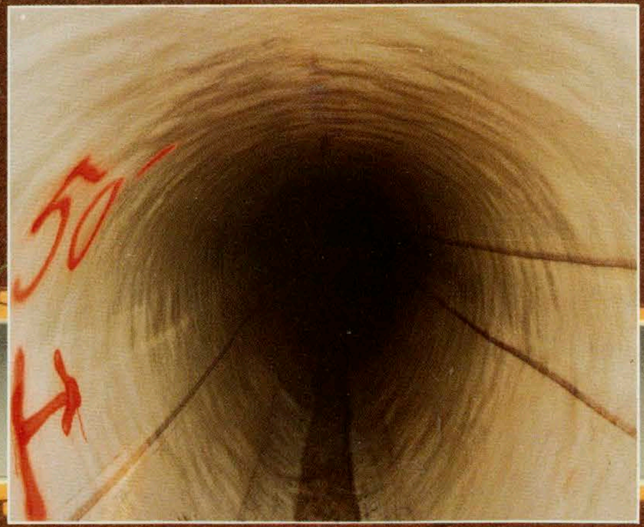




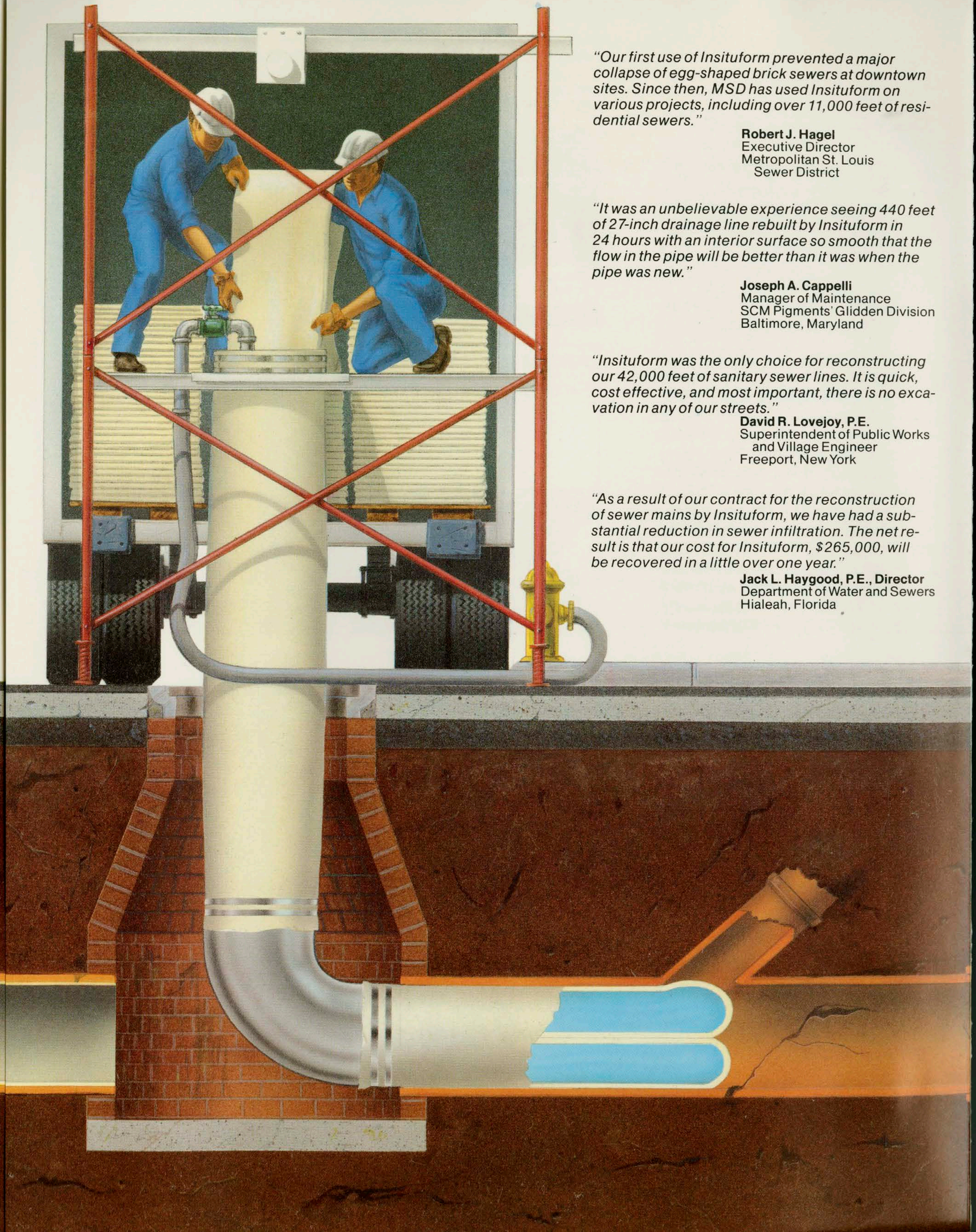




Before—Cracks, holes, and loose joints in the old pipe caused major problems. Exfiltration polluted the environment and infiltration brought in dirt and debris which reduced capacity, impeded flow, and endangered property above ground.



After—Insituform completely replaced the old pipe with a new, stronger pipe. The new pipe's smooth-as-glass interior increases flow, and there are no joints or seams to weaken and break. Leakage and seepage have been totally eliminated.



"Our first use of Insituform prevented a major collapse of egg-shaped brick sewers at downtown sites. Since then, MSD has used Insituform on various projects, including over 11,000 feet of residential sewers."

Robert J. Hagel
Executive Director
Metropolitan St. Louis
Sewer District

"It was an unbelievable experience seeing 440 feet of 27-inch drainage line rebuilt by Insituform in 24 hours with an interior surface so smooth that the flow in the pipe will be better than it was when the pipe was new."

Joseph A. Cappelli
Manager of Maintenance
SCM Pigments' Glidden Division
Baltimore, Maryland

"Insituform was the only choice for reconstructing our 42,000 feet of sanitary sewer lines. It is quick, cost effective, and most important, there is no excavation in any of our streets."

David R. Lovejoy, P.E.
Superintendent of Public Works
and Village Engineer
Freeport, New York

"As a result of our contract for the reconstruction of sewer mains by Insituform, we have had a substantial reduction in sewer infiltration. The net result is that our cost for Insituform, $265,000, will be recovered in a little over one year."

Jack L. Haygood, P.E., Director
Department of Water and Sewers
Hialeah, Florida

Insituform for no-dig pipe replacement

Digging up streets is a dirty, messy, time-consuming, and expensive process. It can also be dangerous, unsightly and a serious disruption to neighborhoods and businesses. It may even be a political liability. It most certainly will be a highly sensitive issue and a constant irritant to the person responsible for the project.

The conventional method of pipe replacement, shown on the left, could take months. If the replacement occurs in a business district, the disruption of traffic could be disastrous to store owners. Compare that method with the Insituform way, shown on the right, which can *replace those old pipes with a better product in a fraction of the time.*

For a cost effective, better than new means of reconstruction without disruption, do what more and more cities, sewer districts and industrial plants across the country are doing. Turn to Insituform.

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OFFICE OF THE STATE ENGINEER
DIVISION OF WATER RESOURCES
1313 Sherman Street - Room 818
Denver, Colorado 80203
(303) 866-3581

NAME OF DAM: ______________________, WATER DIV ______, DAMID __________, C- __________

DATE RECEIVED: ____________ APP COMPLETE? YES _____ NO _____, DATE RETURNED: ____________

DO NOT WRITE ABOVE THIS LINE

APPLICATION FOR REVIEW OF PLANS AND SPECIFICATIONS
FOR THE CONSTRUCTION OR ENLARGEMENT OF A DAM AND RESERVOIR
(File in duplicate, original signatures required on both)
(PLEASE PRINT OR TYPE THE APPLICATION)

CHECK ONE: New Dam________, Enlargement*________

[SEE C.R.S. 37-87-101, et al. and Regulations]
[for Dam Safety and Dam Construction]

I, ____,
(Name of Owner)

owner, hereby accept and approve the enclosed plans and specifications for submittal to the State Engineer in accordance with Section 37-87-105, C.R.S.

____
Signature of Owner/or Agent (DATE)

Address: ____
Street or P.O. Box, City, State, ZIP Code

Phone Number ( ) ______________________

Owner Code: (CHECK ONE): Corps of Eng.(C)_____, Other Federal(G)_____, District(D)_____
County(K) _____, Municipal(M) _____, Private(P) _____, State(S) _____.

NAME OF DAM: ________________________________(*ON FILE WITH THE STATE ENG)

Also Known As: ____

RESERVOIR NAME: ____

STATE ENGINEER'S FILE NUMBER ______________(*ON FILE WITH STATE ENGINEER; i.e., C-NNNNX)

Location: _____ PM, Twnshp. ____, Rng. ____, Sec. ____, Lat. ____, Long. ____ County ______________

Stream Name: ______________________, Tributary To: ______________________

GENERAL INFORMATION

Purposes of Dam and Reservoir ____
(Augmentation, Diversion, Domestic, Erosion Control, Evaporation, Flood Control, Fire Control, Fish, Hydroelectric, Industrial, Irrigation, Mining, Municipal, Pollution Control, Recreation, Stockwater, Settling Ponds, Sewage, Tailings, Waste Disposal)

Consulting Engineer: ____

Company: ____

Address: ____
Street or P.O. Box, City, State, ZIP Code

Phone Number: ( ) ____________ Colorado P.E. Registration Number: ______________

Owner's Responsible Person: ____

Address: ____
Street or P.O. Box, City, State, ZIP Code

Phone Number: ( ) ______________ (primary) ( ) ______________ (secondary)

(CONSTRUCTION OR ENLARGEMENT)

DESCRIPTION OF DAM AND RESERVOIR

Type of Dam - (Check Type)

Concrete _____ Gravity _____ Arch _____
Earthfill _____ Zoned _____ Homogeneous _____
Rockfill _____ Zoned _____ Impervious Membrane _____
Masonry _____ Other _____

Hazard Classification: _____ I, ______ II, _____ III, _____ IV

STRUCTURAL DATA

Dam (Dimensions to nearest tenth, volume to nearest acre-foot or cubic-yard, areas to nearest acre)

Jurisdictional Height ________ ft. (Natural surface of ground to bottom of emergency spillway at longitudinal centerline)
Embankment Height ________ ft. (Jurisdictional height plus emergency spillway freeboard)
Structural Height _________ ft. (bottom of cutoff trench to crest of dam at centerline)
Crest Length _______ ft.; Crest Width _______ ft.; Crest Elev. _______ ft., M.S.L.,
Embankment Volume _______ C.Y.
Maximum Impoundment Capacity _______ Acre-Feet (to crest of dam)
Normal Reservoir Capacity _______ Acre-Feet (at high water line)
Reservoir Surface Area _______ Acres (at high water line)
U/S Slope _________:1, D/S Slope _________:1

Upstream (U)/Downstream (D), Facing Material (Place U or D as appropriate)

Concrete Dam _____, Concrete Facing _____, Clay _____, Gabions _____, Gravel _____,
Handplaced riprap _____, Masonry Dam _____, Natural _____,
Planted _____, riprap with Bedding _____, riprap with No Bedding _____, Rock Zone _____,
Soil Cement _____, Steel _____, Wood _____, Other? (Describe) ____________________

Outlet

Outlet Diameter: __________________________ Inches/Feet Type: ____________________

Comments: ____

____

____

Maximum Discharge Capacity _______ cfs (Reservoir at high water line)

Spillway

1. Type _____________; (i.e., Emergency, Principal)
   Material _____________; (i.e., Natural, riprap, Concrete, CMP, RCP, etc.,)
   Width (Diam) _____ ft., Freeboard _______ ft., Capacity _______, cfs

2. Type _____________; (i.e., Emergency, Principal)
   Material ____________; (i.e., Natural, riprap, Concrete, CMP, RCP, etc.,)
   Width (Diam) _____ ft., Freeboard _______ ft., Capacity _______, cfs

   Total Spillway Capacity _______ cfs, (Crest of the dam)

HYDROLOGIC DATA

Drainage Area _______ Acres, or _______ Sq. Miles
Inflow Design Flood _______, (i.e., 100-year, % PMP, etc.) Duration ____ Hrs
Type ? _______________,(i.e., Thunderstorm, General, Snowmelt, Combination) Ref. _______
Peak Discharge _______ cfs; Volume _______ A.F., Time of Concentration (Tc) _______ Hrs.
Method of Determination ____

____

Inflow Design Flood routes through reservoir with _______ ft. residual freeboard.

OFFICE OF THE STATE ENGINEER
DIVISION OF WATER RESOURCES
1313 Sherman Street - Room 818
Denver, Colorado 80203
(303) 866-3581

NAME OF DAM: ______________________, WATER DIV ______, DAMID ________, C- ________

DATE RECEIVED: ____________ APP COMPLETE? YES ____ NO ____, DATE RETURNED: ____________

DO NOT WRITE ABOVE THIS LINE

APPLICATION FOR REVIEW OF PLANS AND SPECIFICATIONS FOR THE ALTERATION, MODIFICATION, OR REPAIR OF A DAM AND RESERVOIR

(File in duplicate, original signatures required on both)
(PLEASE PRINT OR TYPE APPLICATION)

CHECK ONE: Alteration ____, Modification ____, Repair ____

[SEE C.R.S. 37-87-101, et al. and Regulations]
[for Dam Safety and Dam Construction]

I, ____,
(Name of Owner)

owner, hereby accept and approve the enclosed plans and specifications for submittal to the State Engineer in accordance with Section 37-87-105, C.R.S.

____
(Signature of Owner/Agent) (Date)

Address: ____
Street or P. O. Box City, State, ZIP Code

Phone Number ( ) ____________________

Owner Code: (CHECK ONE): Corps of Eng.(C), ____ Other Federal(G), ____ District(D),____
County(K), ____ Municipal(M), ____ Private(P), ____ State(S), ____.

NAME OF DAM ______________________________(ON FILE WITH THE STATE ENG

Also Known As: ______________________________

RESERVOIR NAME ______________________________

STATE ENGINEERS FILE NUMBER ______________ (ON FILE WITH THE STATE ENGINEER) (i.e., C-NNNNX)

Location:____ P.M., Twnshp. ____,Rng. ____,Sec. ____,Lat.____,Long.____,County______________

Stream Name: ______________________, Tributary to: ______________________

Description of Work: ______________________________

Work will result in ______________ of reservoir capacity.
(no change, lowering)

(ALTERATION, MODIFICATION, OR REPAIR)

GENERAL INFORMATION

Purposes of Dam and Reservoir ______________________________
(Augmentation, Diversion, Domestic, Erosion Control, Evaporation, Flood Control, Fire Control, Fish, Hydroelectric, Industrial, Irrigation, Mining, Municipal, Pollution Control, Recreation, Stockwater, Settling Ponds, Tailings, Waste Disposal)

Consulting Engineer: ______________________________

Company: ______________________________

Address: ______________________________
Street or P. O. Box City, State, ZIP Code

Phone Number ( ) ______________ Colorado P.E. Registration Number ______________

Type of Dam (Check Type)

Concrete ____, - Gravity ____, Arch ____.
Earthfill ____, - Zoned ____, Homogeneous ____.
Rockfill ____, - Zoned ____, Impervious Membrane ____.
Masonry ____
Other ______________________________.

DESCRIBE STRUCTURAL CHANGE TO DAM/RESERVOIR (as appropriate)

Jurisdictional Height _____ ft. (Natural surface of ground to bottom of emergency spillway) at longitudinal centerline)

Embankment Height ______ ft. (Jurisdictional height plus emergency spillway freeboard)

Structural Height ______ ft. (Bottom of cutoff trench to crest of dam at centerline)

Crest Length: ______________ Ft.

Crest Width: ______________ Ft.

Maximum Impoundment Capacity: ______________ Acre-Feet (to crest of dam)

Normal Reservoir Capacity: ______________ Acre-Feet (at high water line)

Reservoir Surface Area: ______________ Acres

Slopes: ______________
Upstream, Downstream

Upstream Facing: ______________________________

Downstream Facing: ______________________________

Describe Structural Change to Outlet: (ENTER N/A IF NOT APPLICABLE)

Description: ______________________________
Size, Type, Capacity

____

____

Describe Structural Change to Spillway: (ENTER N/A IF NOT APPLICABLE)

Description: ______________________________
Type, Material, Width, Freeboard Capacity

____

____

OFFICE OF THE STATE ENGINEER
DIVISION OF WATER RESOURCES
1313 Sherman Street - Room 818
Denver, Colorado 80203
(303) 866-3581

NAME OF DAM: ______________________, WATER DIVISION ______, DAMID ____________

DATE RECEIVED: __________ APP COMPLETE? YES ____ NO ____, DATE RETURNED: __________

DO NOT WRITE ABOVE THIS LINE

APPLICATION FOR REMOVAL OR BREACH OF A DAM

(File in duplicate, original signatures required on both)
(PLEASE PRINT OR TYPE THE APPLICATION)

[SEE C.R.S. 37-87-101, et al. and Regulations for Dam]
[Safety and Dam Construction]

I, ____,
(Name of Owner)

owner, hereby make application for the removal/breach (underline appropriate one) of

______________________________________ dam and reservoir
(Name of Dam)

____
Signature of Owner/or Agent (DATE)

Address: ____
Street or P.O. Box, City, State, ZIP Code

Phone Number ( ) ______________________

Location: P.M. ______, Twnshp. ____, Rng. ____, Section ____, County __________

State Engineer's File Number C - __________ (if known)

State Engineer's DAMID: __________ (if known)

FILL OUT THE FOLLOWING IF DAMID DOES NOT EXIST

Type of Dam ____
(Earth, Concrete, etc.)

Height to crest from downstream toe ______________________________ Ft.

Spillway Freeboard ____________________ Ft., Width ____________________ Ft.

Crest Length ______________ Ft., Width ______________ Ft.

Upstream Slope ______________, Downstream Slope ______________

Volume of Embankment Material ______________ C.Y.

Reservoir Capacity ______________ A.F.

Hazard Classification ____________________
I, II, III, IV

State reasons for removing/breaching dam ________________

Describe method and extent of removal/breach ________________

Describe provisions for controlling run-off/floods during removal/breaching ________________

Former purpose of dam and reservoir (i.e., diversion, irrigation, municipal, etc.) ________________

Name of Engineer ________________ P.E. No. ________

Address ________________

City, State, ZIP

Telephone (   ) ________________

Describe sediment control plan during removal/breaching ________________

What agency was contacted to obtain approval of water pollution control plan? ________________

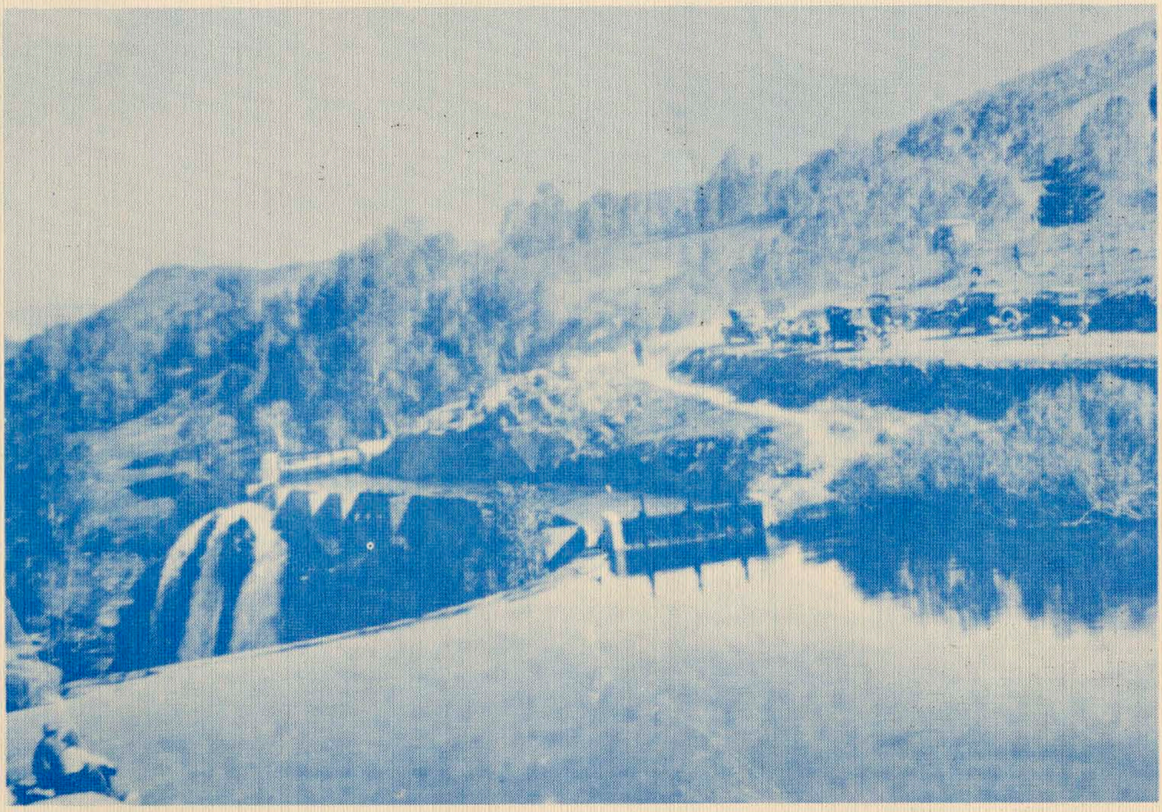
Agency Name Address Telephone No.

Contact ________________

Name

Snowy Caps to Loveland's Taps

A History of the Loveland Water Utility



City of Loveland
Water/Wastewater Department

Snowy Caps to Loveland's Taps

A History of the Loveland Water Utility

By Laurie D'Audney

June 1989

City of Loveland
Water/Wastewater Department

Special Thanks to

Dean Bach
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Ralph Mullinix
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Johnny Tuxhorn

Table of Contents

INTRODUCTION

This book has been written in an attempt to capture events and changes that have taken place in the Loveland Water Department during the past one hundred years of service to this community.

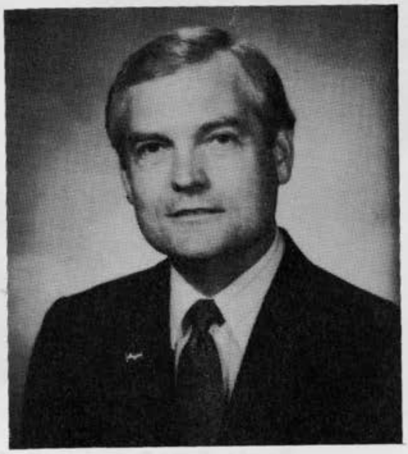
The challenges that confronted the early settlers in the late 1800s were monumental. To think that they could dream of, and build, a complete water system from nothing is astonishing. During the past century, Loveland has increased in geographical size and the population has grown from a few hundred residents to over thirty-seven thousand. The emphasis on agriculture in the area has decreased as manufacturing has expanded. But as these changes occurred, and still occur, the primary vision remains — to create a "quality of life" existence in Loveland. A dependable, high quality water system is one of the many foundations needed to achieve that goal.

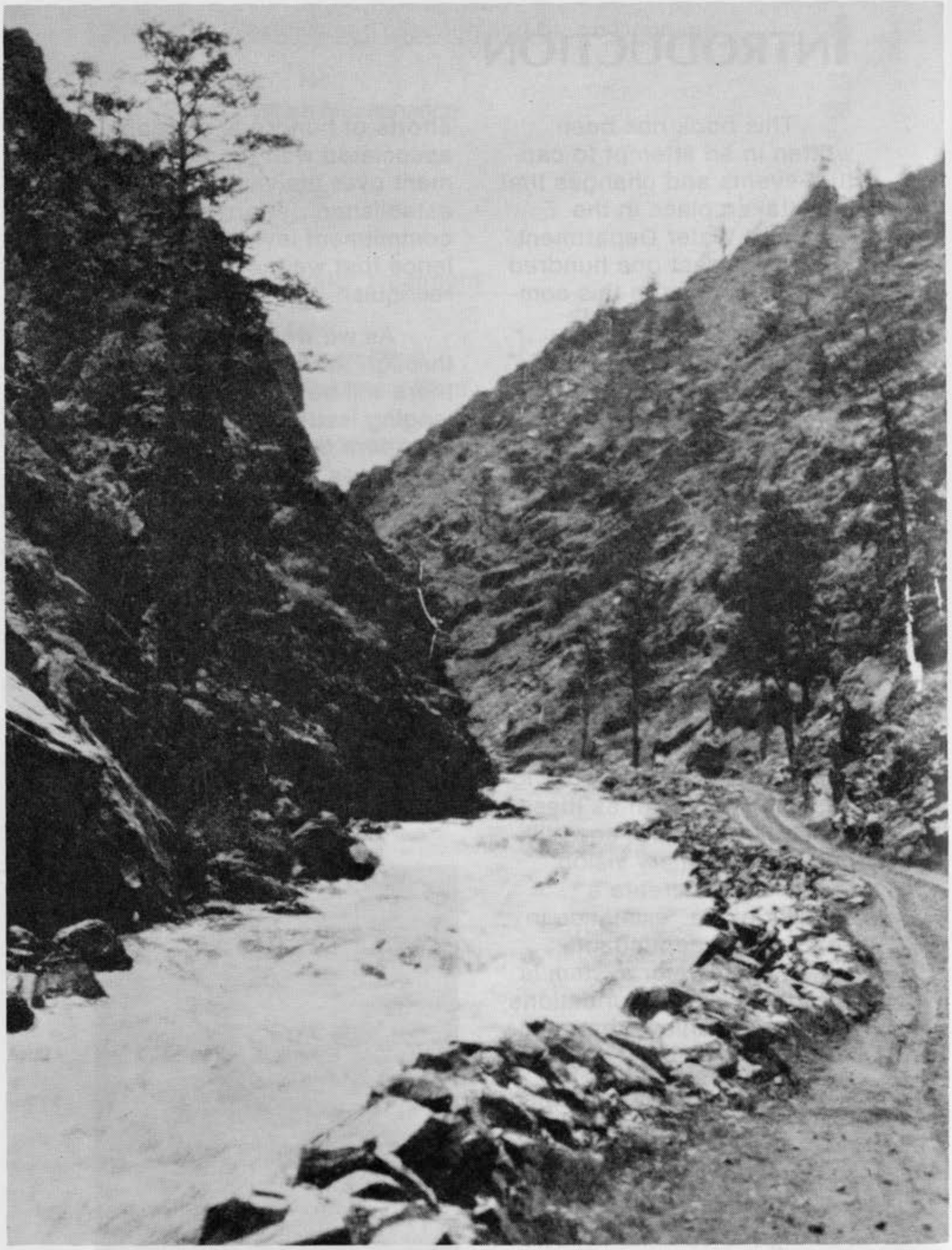
As we attempted to record the journey from that first log water system to today's modern facilities, we were reminded again and again of the importance of serving the community. The efforts of hundreds of people associated with the department over the years has established performance and commitment levels of excellence that we must never relinquish.

As we work our way through the next century, there will be new and challenging issues to face. I am confident that Loveland will face those issues with the same pioneering spirit that has prevailed for the past one hundred years.

A special thank you to Laurie D'Audney for her hard work and special talents in researching, interviewing and writing this document.

Ralph Mullinix
Director





Road to Estes Park along the Big Thompson River - circa 1900

Chapter 1

THE EARLY HISTORY

Loveland's water story begins with the Big Thompson River. Before the arrival of the white man, Arapaho hunting parties would ride through the valley and camp along the river near the sulphur spring that bubbled out of the ground on the southeast side of Mariana Butte.

Explorers wending their way westward used the river as a natural pathway through the wilderness. From 1837 to 1842, Philip Thompson explored, trapped, and traveled along the river known to the Indians as the Big Pipe. Thompson, in his exploration of the river now named for him, may have been the first white man to travel through the valley. John C. Fremont's expedition followed the Big Thompson River in 1843. Fremont described it as a "fine stream, sixty-five feet wide and three feet deep."

Mariano Medina

Fur trappers camped on its banks in search of beaver and other animals. Brothers Nicholas and Antoine Janis set up a trapper's camp along the Big Thompson River and stayed several years before moving on. Mariano Medina arrived at

Fort Namaqua

their camp in the summer of 1858. Medina had a colorful background as guide, interpreter, and mountain man and was the first permanent settler in the Big Thompson Valley. He claimed to have traveled with Fremont's party as interpreter and introduced Kit Carson as an old friend when Carson visited him in 1868.

As the demand for beaver decreased, mountain men started looking for permanent locations for their new homes. Prospectors who failed to make their fortunes in the Colorado goldfields took a second look at the dry land of the High Plains, which the explorers Zebulon Pike and Major Steven Long described as a virtual desert. The Big Thompson Valley had much to offer: plentiful water supply, wild game, timber for cabins, forage for cattle, and maybe even gold!

Settlements mushroomed along the streams where mountain men had camped. Medina built a toll bridge across the Big Thompson and forced travelers to cross his bridge by fencing his land. His settlement, called Namaqua, included a fort and a combination saloon and store on the north side of the river, and rental cabins on the south side.

In 1862, trouble with the Indians along the North Platte River caused the Overland Stage to change its route to follow the Cherokee Trail, a path used by the Cherokee Indians on their trading expeditions to the Northwest. The stage had to cross Medina's bridge, and Namaqua became a stage stop. By 1876, Namaqua had been eclipsed by the town of St. Louis, later called Winona, located three miles downstream.

In 1861, three years after Mariano Medina settled on the Big Thompson, Colorado was organized as a territory. Larimer County was created shortly thereafter with a population of only 100 people. That year drought caused a partial crop failure; so settlers diverted water from the streams to save their gardens and potato patches. During the 1860s and '70s, agriculture in the area grew and so did the need for water. With an annual rainfall of less than 15 inches, the settlers felt the importance of water from the beginning.

WATER RIGHTS

Laws concerning surface water were written into the Constitution when Colorado became a state in 1876. The Constitution declared that the water of every natural stream is public property, and it established an appropriation system for determining how individuals acquire rights to use water.

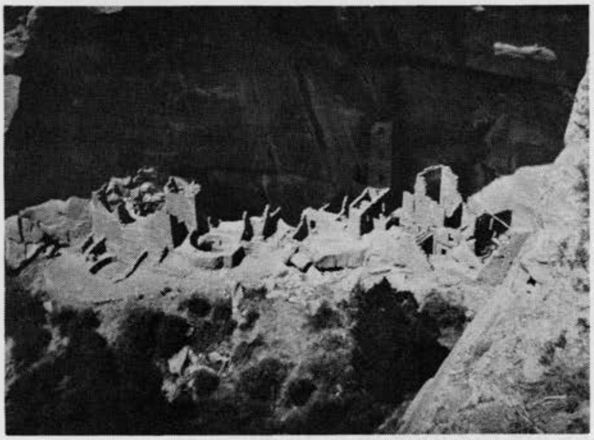
Under the system, persons may appropriate water even though they intend to use the water far from the stream. The law states that whoever first claims the water for beneficial use has established the right to use it. The date of appropriation then becomes the basis for determining which rights are senior and which are junior. This principle of "first in time, first in right" is known as the Doctrine of Prior Appropriation. It differs from the Riparian Doctrine found in the humid east, where owners of land along a stream are entitled to full use of the water, as long as it is undiminished in quality or quantity.

Two main classes of appropriation were identified in the Constitution:

1) Diversion of water from the stream for immediate use (direct flow rights).

2) Diversion from the stream for storage for later use.

A direct flow appropriator cannot store his water for later use, and the storage appropriator usually may fill his reservoir only once a year. In each of the two main classes, uses were also prioritized in order of importance: domestic, agricultural, and then, manufacturing and mining.



Cliff Dwellings at Mesa Verde

Colorado became a leader in the legal concept of water rights, now generally adopted in all western states. This original concept dates back to the California gold rush of 1848, when miners had to divert water from nearby streams to wash their gold. Disputes over water were settled by fists, guns, and shovels, with the winner of the fight getting the water. An informal set of rules developed regarding water in the goldfields.

It became accepted practice that the miner who first used the water had the first right to it, even if another miner's claim was closer to the stream. The second miner to use the stream had the second right to it and so on down the line. Miners brought this system with them when they came to Colorado during the gold rush of 1859.

Later, as the gold boom died out, some miners moved down onto the plains and applied this same concept to their new agricultural interests along the river valleys.

HISTORY OF IRRIGATION

Water played a key role in the settlement of this semi-arid land long before the white man appeared on the scene. Remnants of dams and terraces at Mesa Verde give evidence of an ancient irrigation system, perhaps in use by 1000 AD, that permitted the Anasazi Indians to grow their crops with a meager water supply. In spite of their skillful management of soil and water, the Cliff Dwellers disappeared, perhaps because of prolonged droughts.

The first white settlers in the Big Thompson Valley lived along the river banks with easy access to the abundant water. They grew oats, beans, wheat and potatoes. Apple trees were first planted in 1871. By 1920, one and a half million pounds of cherries were being produced in the valley annually, and

An early farmer standing behind a walking plow

Loveland claimed to be the largest producer of red raspberries in the country.

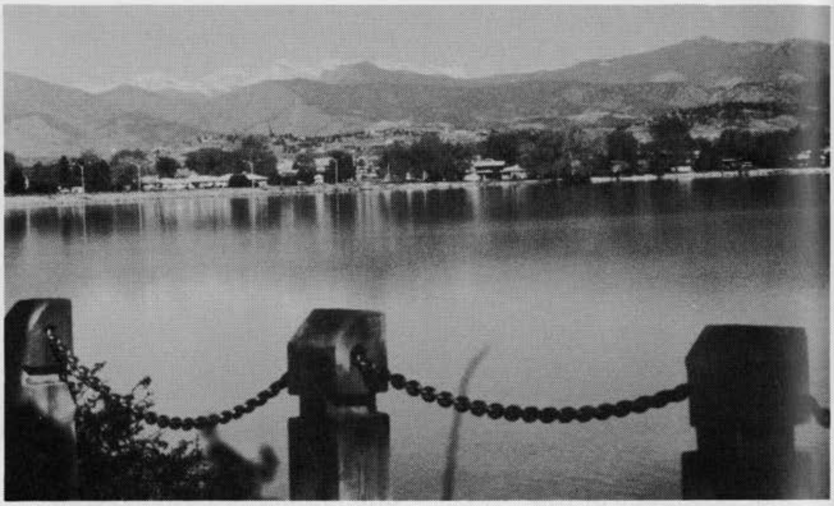
Settlers eventually banded together to construct small ditches that allowed irrigation of the arid lands above the flood plain. As the population of the area grew, and the land farther from the river was settled, companies formed to build bigger ditches. Landowners and farmers usually were the stockholders. Each stockholder was responsible for digging and maintaining the ditch across his own property.

The Big Thompson Ditch Company was granted the earliest appropriation date of 1861, and other companies soon followed. The Chubbuck Ditch, built by a group of farmers in 1867, was the first to bring Big Thompson water to the bluffs above the river. As the ditches proved successful, irrigated agriculture expanded rapidly.

When David Barnes and his family arrived in 1873, they moved to a 320-acre farm on a bluff north of the Big Thompson River. The Barnes farm was bounded on the west by what is now Garfield Avenue, on the east by Monroe Avenue, on the north by 14th Street and on the south by First Street.

His daughter Lena recalled, "It was a bleak prairie, nothing in sight but prairie dogs, rattlesnakes and hoot owls." Hauling water to irrigate was a difficult and time-consuming task, so Mr. Barnes constructed a ditch to divert water to his land. Today, still in operation, it is known as the Barnes Ditch.

View of Lake Loveland today



LAKE LOVELAND

Along with building ditches, reservoirs were constructed to store spring flood water for summer use. A small pond known as Hays Lake, located at the bottom of a great natural depression about a half-mile north of town, was the scene of early cattle roundups. In 1894, the Greeley and Loveland Irrigation Company used this site to construct a reservoir named Lake Loveland.

The depression was a natural reservoir site, with uniform slopes needing little embankment. The Barnes Ditch carried water from the Big Thompson River to fill the reservoir during the spring; and the stored water was let out into the Loveland and Greeley Canal (originally the Chubbuck Ditch) during the irrigation season. That system continues to operate today.

Connecting the lake to the canal, a mile south, was a challenge. The first half-mile was constructed as a tunnel through soft sandstone, lined with concrete or brick. A circular culvert five feet in diameter, lined with bricks, ran the next 2,400 feet. The last 250 feet to the canal was an open channel.

A brick water tower, seven feet in diameter, was built offshore to house the machinery used to raise and lower the control gates. The reservoir was first filled during the spring of 1895, capturing 12,000 acre-feet of water. Over 4,500 men worked on the project, which used some 650,000 bricks held together by 1,500 barrels of concrete.

EARLY WATER DIVERSION

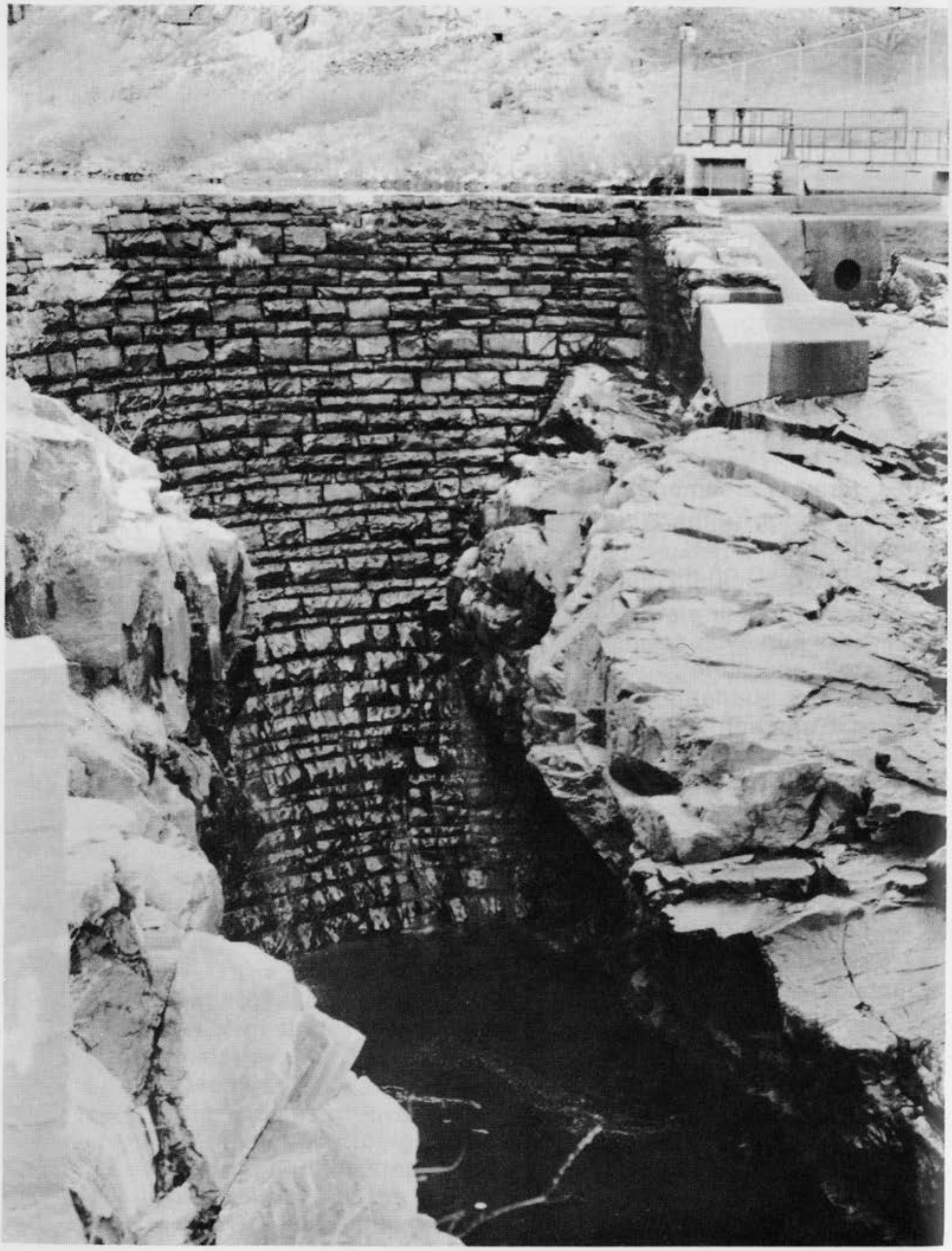
Colorado's water shortage stems not so much from a lack of water, but from the uneven distribution of it. Although about 80% of Colorado's precipitation occurs on the Western Slope, the most fertile farmland lies east of the Continental Divide. As early as the 1880s, farmers dreamed of importing water from western Colorado to the Great American Desert on the east.

After conducting a preliminary survey in August 1884, Colorado State Engineer E.S. Nettleton decided it was not feasible to divert mountain water from the Western Slope. In his report, he stated: "A tunnel of 14 to 17 miles is entirely impractical to construct."

Henry Joseph Heinricy, a local farmer, for many years searched the Rocky Mountains west of Loveland for sources of water. "Eureka!" Heinricy exclaimed when he finally located a site on the Western Slope along the top of Flat Top Mountain, now part of Rocky Mountain National Park.

He approached the Louden Ditch Company for backing to construct a ditch to divert water to the Big Thompson Basin. After they turned him down, he went to B.D. Sanborn of Greeley, a man known to be interested in irrigation projects. Sanborn's influence resulted in twenty men from Greeley each contributing $100 to finance the project.

In 1902, Heinricy's dream came true as the Eureka Ditch began diverting water across the Continental Divide into the Big Thompson River. This farsighted pioneer has been called by some the father of the Colorado-Big Thompson Project.



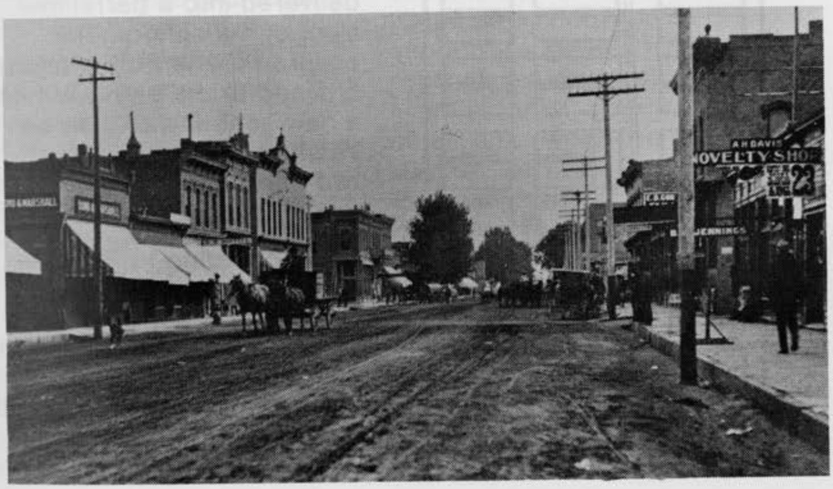
The Big Dam

Chapter 2

Pioneer Loveland

The history of Loveland began with the completion of the Colorado Central Railroad from Golden to Cheyenne in 1877. The best route for the line was through David Barnes' farm. Barnes laid out the streets of a new town after he finished harvesting his wheat and oats in 1877. He named the new town Loveland after his friend William Austin Hamilton Loveland, president of the Colorado Central Railroad. After the town was platted, Barnes brought 1,200 cottonwood trees from the Platte River and planted some on every street.

St. Louis, located a mile farther down the river from the Barnes farm, had become the commercial center for the entire valley. When lot selling began in Loveland, many businesses, including

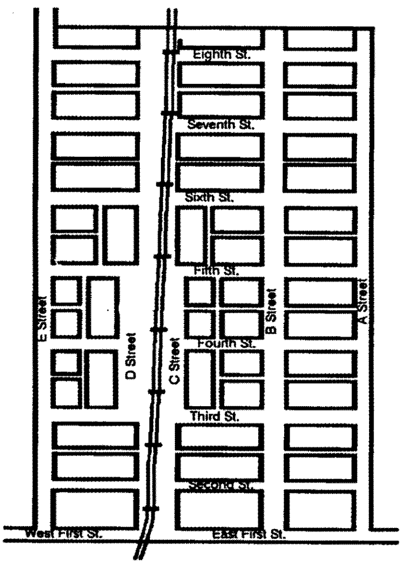


Early downtown Loveland - circa 1905

the Post Office, moved to the new site. By June 1878, 18 businesses were settled on Main Street (Fourth Street). Corner and business lots sold for $100 each.

The town, as first established, ran from A Street (Lincoln Avenue) west to E Street (Garfield Avenue) and from First Street north to Eighth Street. Main Street became the main business street, and B Street (Cleveland Avenue) the main north-south street.

The formal organization of Loveland took place May 11, 1881. Just a year after the city's founding, its population was 250. The town was an instant success. Three factors contributed to its growth – its location along a major north-south rail line, its situation half way between Longmont and Fort Collins, and the ample supply of dependable water from the Big Thompson River.



Original plat of the Town of Loveland

WATER BY THE BARREL

Loveland's first public water supply flowed from the Barnes Ditch along the streets in small ditches. This was supplemented in freezing weather by water delivered in 50-gallon whiskey barrels from tank wagons. The price for water bailed from or pumped up from the Big Thompson River was 25 cents a barrel. Foote and Stoddard's livery stable were the principal merchants.

Water for pupils at the public school (Fourth Street and Cleveland Avenue) was delivered into a barrel in front of the school. The children drank from a tin cup chained to the barrel. When a new school was built on Washington Street, it had two barrels with the luxury of two tin cups for each.

According to Eugene Smith, pioneer resident, large sucker fish once escaped into the Barnes Ditch. Fish were scooped up into barrels out of the laterals all over town, and out of

Bartholf Hose Team - circa 1884

gardens where water happened to be running.

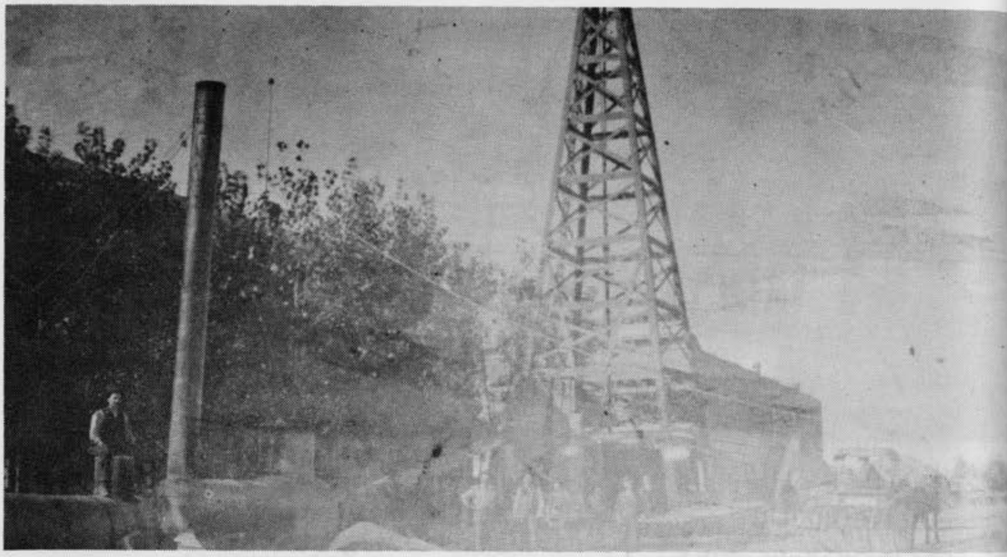
For the benefit of the farmers who came to town and their horses, an open well was dug in the middle of Fourth Street. The well had boards around it about three feet high with a pulley over the top. As a bucket of water was pulled up, another bucket went down.

Later, for fire protection, two 12-foot cisterns were dug and kept filled with water. Hand pumps, with hoses and handles for four men, were installed in each cistern. Large, heavy sheets of flagstone covered the cisterns in the middle of Fourth Street.

Before 1883, Loveland had no organized fire department, only a volunteer bucket brigade. That year two volunteer hose companies developed – the Bartholf Hose team and the Loveland Hook and Ladder. Loveland never had fire wagons drawn by horses. The men themselves, in harness, pulled the equipment.

THE ARTESIAN WELL

When Loveland's flour mill and grain elevator were destroyed by fire in 1885, it became evident that the cisterns did not provide enough water. This trauma precipitated residents to issue a $5,000 bond to drill an artesian well. The Fort Collins Artesian Well and Drilling Company, Swan brothers proprietors, were hired to drill the well on the southwest corner of Fourth Street and Cleveland Avenue. The bonds did not provide sufficient funds to reach a good supply of water, and in 1886 a second series of bonds were issued to continue the



Construction of the Artesian Well

well "to not more than 3,000 feet." The well construction stopped at 2,742 feet when a small flow of water came to the surface. After cleaning out the well and installing a two-inch pipe, the flow of water increased to 40 barrels a day. Hopes were high for a suitable water supply. But soon only a trickle of water flowed, with a high concentration of mineral salts and unpleasant to the taste. As a means of supplying the town with good soft, wholesome water, the $14,000 well was a failure.

A circular stone fountain was erected over the well and the people of Loveland sampled the water. On April 26, 1900, the Loveland Reporter stated, "Nearly every traveling man visiting Loveland heads for the artesian well and swallows a lot of the mineral water bubbling from it. They claim many merits for the water, as do many of our own citizens. Soon the town will bottle and ship this water to many points, so great are its medicinal properties."

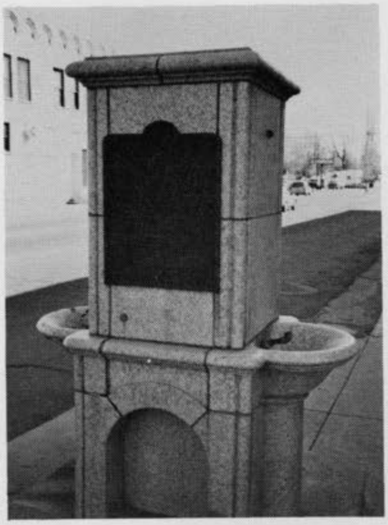
Eugene Smith tells the story of the day the water wagon failed to deliver water to his mother's barrel. She sent him to the artesian well for a bucket of water to make some tea. The tannin in the tea leaves, combined with the minerals in the water, made a fiery red concoction; the most vile he ever tasted.

Besides the mineral water, the well also produced a natural gas. An effort was made to use this gas to light the Bartholf-Allen Opera House (located on the same corner as the well) for a production of "Uncle Tom's Cabin," but this was not a success either. The flow was too uneven, and the lights failed in the middle of the first show.

The circular fountain was replaced in 1932 by a terra cotta one with two spigots – mineral water on the east side (lit with gas from the water) and city water on the west (lit with electricity). Harold Marion Dunning attached a bronze plaque to the fountain in memory of David Barnes. Well water continues to flow from the fountain, but its taste has not improved with the years. The well, the deepest ever drilled in Colorado, was made famous when Ripley featured it in his "Believe It or Not" column in January 1941.

THE WATER WORKS

The failure of the well to meet expectations led to a demand for a new water system. After an election on October 11, 1886, the Town issued $40,000 worth of bonds for the construction of



Terra cotta fountain over the artesian well - 1989

a nine-mile pipeline to serve the town.

With a water supply assured, the town trustees in March 1887 established a Department of Water Works. Ordinance 27 provided for water rates, meters, a superintendent and even licensing of plumbers. Soon to follow was a network of distribution pipelines and fire hydrants, carrying water to homes and businesses.

Town Councilors W. D. Hemingway, J. J. Ryan, and S. B. Harter were appointed to a temporary Committee on Water Works to oversee the pipeline construction. A permanent Water Works Committee was established in April 1888 with members John J. Ryan, S. B. Harter and Vollie VanBramer.

Looking at the Big Dam from Chasteen's Grove

THE BIG DAM

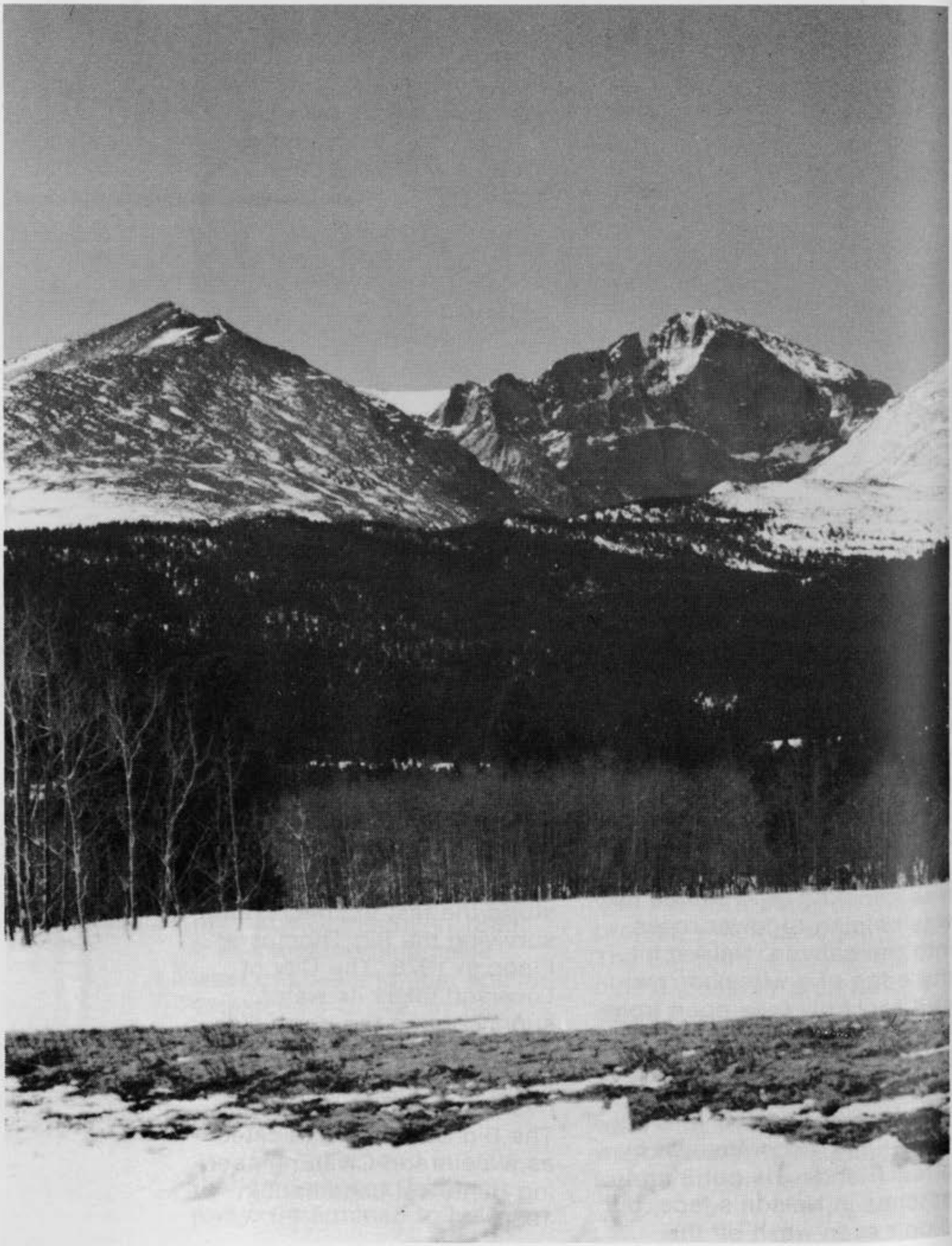
To supply additional water for irrigation, engineer John H. Nelson constructed a log dam on the Big Thompson River for the Home Supply Ditch Company in 1880. It was located nine miles west of Loveland, just above Chasteen's Grove. In 1887, the Town of Loveland built a wooden pipeline to carry water from the dam into the town.

During a flood in 1894, the log dam was washed away. Determined to build a dam that would not wash out, John Nelson designed a stone and concrete dam to take its place. Charles Lester was the primary stone mason, and George Kelly was the contractor on the project, which cost $11,000. The Big Dam is one of the oldest masonry arch design dams in Colorado. The dam is 60 feet high from the bedrock to the top. Rocks weighing up to 2,000 pounds were hauled in by team and wagon and laid in concrete for the bottom layer.

Driving by the Big Dam on the way to Estes Park - circa 1920

Jessie Chasteen Whiteside was living at Chasteen's Grove when her home became headquarters for the construction crew while the dam was being rebuilt. When interviewed by Zethyl Gates in 1972, Mrs. Whiteside related the story of John Nelson's accident. He was knocked off a cliff as he was helping to lower rocks into the canyon. Nelson hit the edge of a wheelbarrow and "split his face open from his forehead to his mouth, just as clean as if you'd done it with a knife." The doctor was summoned and arrived fairly tipsy, accompanied by a few friends. He put 3 or 4 stitches in Nelson's face, but didn't even wash off the blood. Horrified by the doctor's behavior, Jessie's mother cleaned him up, got her needle and thread out of her sewing basket and finished the stitching job. Mrs. Whiteside saw Nelson many years later and he looked "just fine."

Nelson's design has stood the test of time, even surviving the Big Thompson Flood in 1976. The City of Loveland takes its water supply out on the north side of the dam, and the Home Supply Ditch Company carries water out on the south. The Big Dam was dedicated as a Colorado Civil Engineering Historical Landmark in 1986.



Snowfall becomes our water supply in the spring

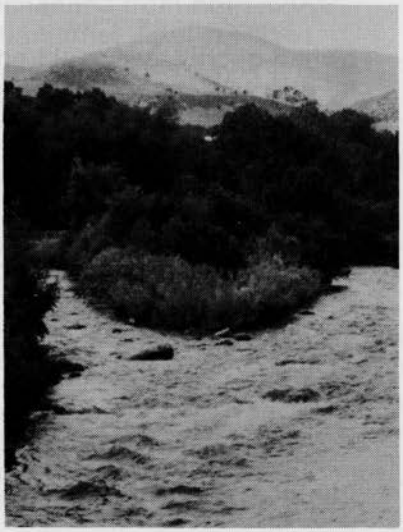
Chapter 3

WATER SUPPLY

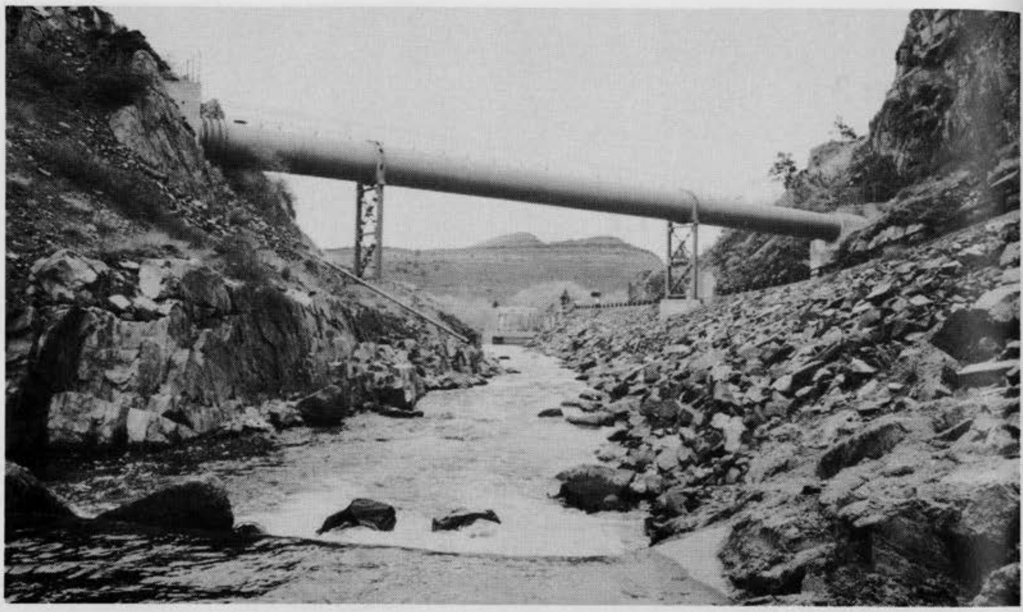
As snow accumulates in the high country, it's good news for the Water Utility. All of Loveland's water originates from mountain snowmelt. In an average year, almost three-fourths of the stream flow volume occurs from May through July.

Today, the sources of water for the Loveland Water Utility are direct flows from the Big Thompson River, City ownership in private ditches (which also derive their water from the Big Thompson River), and water from the Colorado-Big Thompson and Windy Gap projects (which divert water from the Colorado River Basin into the Big Thompson Basin).

The Big Thompson River has historically been Loveland's primary source of water. In July 1881, Loveland purchased its first water rights from Francis E. Everett of Golden. In 1897, the City acquired 3.44 cubic feet per second of direct flow rights from the Hillsborough Ditch Company. This water was part of the earliest filing on the Big Thompson River, dated November 10, 1861. The City acquired additional direct flow rights from the Big Thompson Ditch and Manufacturing Company in 1925. Together, these rights



Water supply from the Big Thompson River



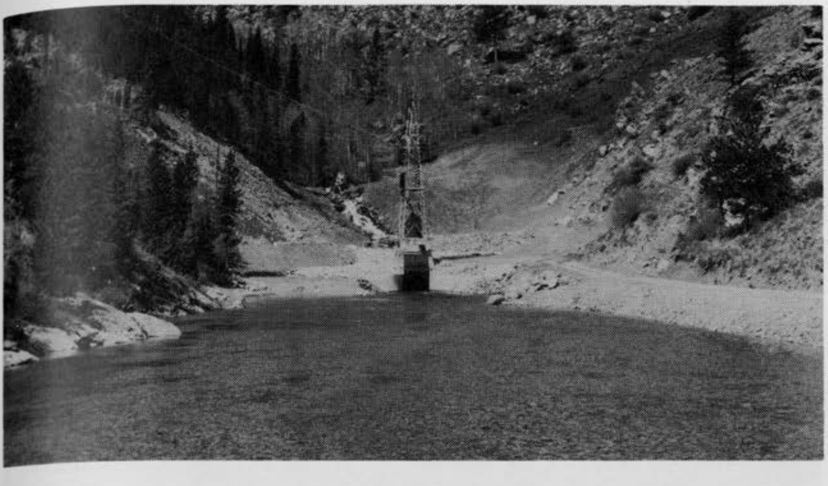
The Big Siphon

supply approximately half of the City's current annual use of 7,200 acre-feet of water. An acre-foot of water is one acre of water one foot deep, or 325,851 gallons.

Before 1985, City-owned ditch water could only be diverted at specific locations, not always at the water treatment plant where it was needed. To use this water, the City had to exchange ditch water for Colorado-Big Thompson water. That year, a Transfer Decree granted the right to divert ditch water at any of several headgates along the river.

COLORADO-BIG THOMPSON PROJECT

In the dry years of the 1930s, the ditches produced very little irrigation water, and the available water on the eastern side of the mountains had already been appropriated. Most of the suitable reservoir sites for storing spring flood water for summer use had been developed by 1910. Farmers and developers alike turned back to the old idea of bringing some of the unused water from the Western Slope over to the east. Since additional Western Slope water couldn't be brought around or over the mountains, the only workable



Outlet portal of the Adams Tunnel

solution was to actually bore through the Continental Divide.

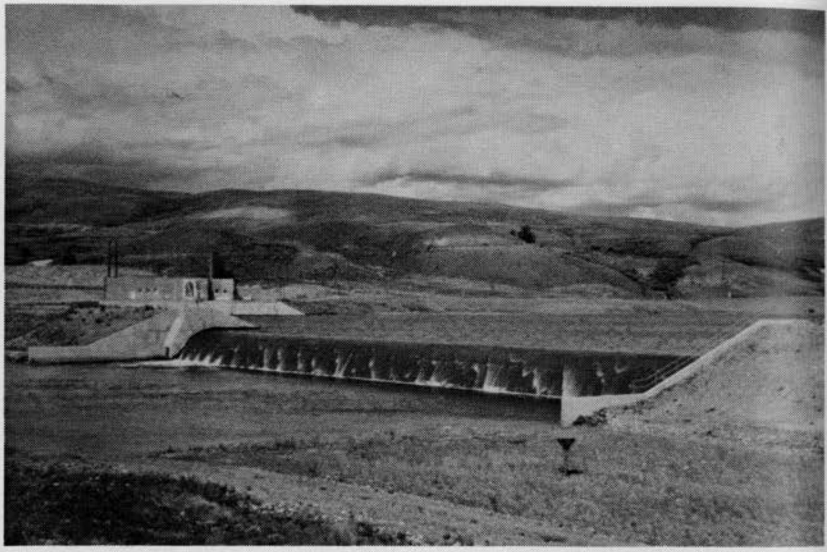
In 1935, $150,000 of Works Progress Administration (WPA) funds were allotted to the Bureau of Reclamation for exploration of the idea. The Northern Colorado Water Conservancy District was organized in 1937 to contract with the federal government to construct and administer the project.

Actual construction of the Colorado-Big Thompson (C-BT) Project, whose waters originate from the headwaters of the Colorado River, began in 1938 with a dam and power plant at Green Mountain on the Western Slope. The project has proven to be of immense importance to Loveland and the surrounding area, supplying irrigation and municipal water, as well as power for industries.

In 1940, the Alva B. Adams Tunnel was bored thirteen miles through a solid granite mountain. The bore was so long that the curvature of the earth had to be taken into account. Drilling commenced from both sides of the tunnel, and when the drillers met in the middle, their surveys were true to within half an inch. The tunnel is 9.75 feet in diameter. Water finally flowed through the tunnel and into the Big Thompson River in June 1947.

The final section of the project was completed in 1959, twenty-one years after construction began. The C-BT project provides supplemental water to about 720,000 acres and more than

Windy Gap Reservoir

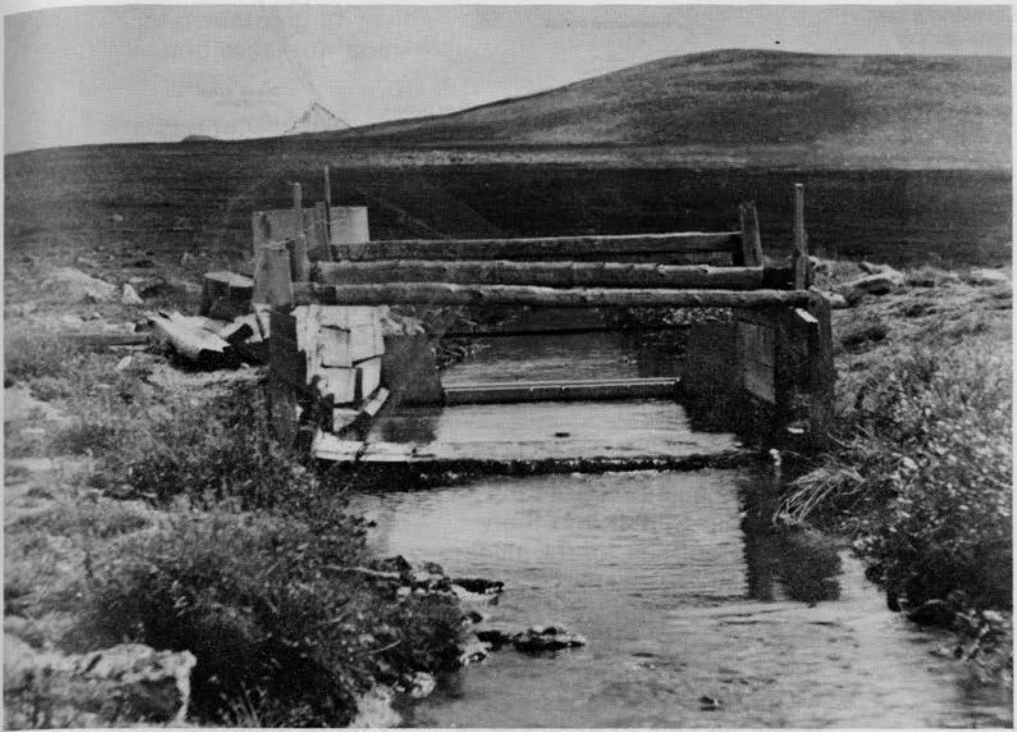


400,000 people in the South Platte River Basin.

Since the quantity and quality of the Big Thompson River water fluctuates throughout the year, C-BT water is used to supplement Loveland's demand. For Loveland to get water from the system, it flows from the Adams Tunnel to Flatiron Reservoir and then is pumped to nearby Carter Lake and into the Charles Hansen Feeder Canal. A turnout constructed by the City diverts C-BT water from the Canal into the City's 600 acre-foot Green Ridge Glade reservoir, north of the water treatment plant.

WINDY GAP PROJECT

In the early 1960s, six cities in northeastern Colorado, including Loveland, banded together to find additional water supplies to serve their growing municipalities. The cities filed for water rights on the Colorado River on July 17, 1967. In 1970, the Municipal Subdistrict of the Northern Colorado Water Conservancy District was formed to develop a new water supply on the Western Slope known as the Windy Gap Project. Surplus runoff water from the Colorado and Fraser Rivers is captured in a dam west of Granby and is pumped from the diversion dam to Lake Granby. The water is stored there until it is transmitted



The Eureka Ditch - 1940

through the C-BT system to the Front Range.

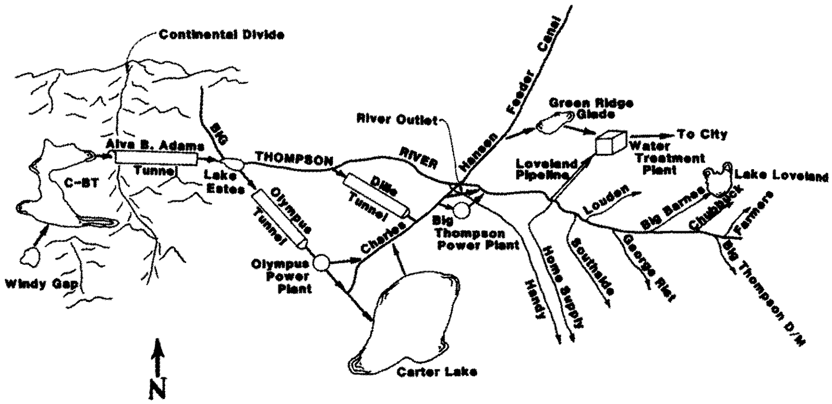
Construction on the project began in July 1981, and it became operational in the spring of 1985. As the project progressed, three of the cities with municipal power systems transferred all or part of their allotment to the Platte River Power Authority. Loveland owns one-twelfth of the project. Although Loveland hasn't needed it yet, water from the Windy Gap Project could provide the City with about 4,000 acre-feet annually.

THE EUREKA DITCH

In 1940, Albert Beebe, who then owned the Eureka Ditch, paid a $40.70 debt by giving the City 200 feet of water service pipeline in the Campion area and all rights to the Eureka Ditch system. For Loveland to continue to claim rights to the water from the ditch, the State requires that the ditch flow routinely be measured.

For 25 years (1938-1963) this was done by the late Earl Denton of Loveland. When interviewed in 1962 by

Loveland's raw water supply sources



Bus Tarbox, Denton said, "I drive 80 miles to Green Mountain Ranch and then ride horseback for 11 miles up Tonahutu Creek. The final two miles to the weir (a box-like measuring device for determining the amount of water flow) are occasionally made on skis or snowshoes over drifts a horse couldn't navigate."

Denton made these trips once a week from the end of May to mid-September to take readings. In 1958, a 30-day clock device was installed to record water flow on a graphite chart. It turned the weekly trips into monthly ones.

Today, the City retains ownership of the Eureka Ditch, and the 30-day clock is still in operation. Each year the City receives credit for approximately 100 acre-feet of water from the ditch. It turned out to be a good trade for the City!

WATER RESOURCE PLANNING

Short- and long-range planning is necessary for the City to maintain adequate supplies of raw water to meet its growing needs. Since drought is a natural unpredictable occurrence in Colorado, Loveland is continuing to plan for future dry periods. To accomplish this, the City has acquired water rights beyond their current needs. Therefore, the City owns more ditch water than it is now using and leases water to area agricultural and industrial users. Before the City serves water to newly developed areas, the developers must transfer water rights to the City to serve that development. So as water use and demand grows, City ownership in local ditch and reservoir companies increases.

In 1986, the City initiated a three-phase drought study to determine future water needs and plan for future water supplies. The first phase of the study determined that Loveland has adequate sources of water to meet present needs, even during a 100-year drought. However, if Loveland grows at a moderate rate for the next 15-20 years, and should a 100-year drought occur during that time, there could be a water shortage.

The second phase of the study evaluated alternatives to meet Loveland's future water supply demand. The preferred alternative was to expand Green Ridge Glade reservoir to a total capacity of 3,500 acre-feet and to purchase extra units of C-BT water. Additional engineering studies and financial impacts of the selected project will be studied in more detail during phase three.

Rapid Sand Filter Building - built in 1924

Chapter 4

WATER TREATMENT

Raw water becomes drinking water at the City's water treatment plant located in Chasteen's Grove nine miles west of Loveland, on the north side of the Big Thompson River.

When the Loveland area was first settled, the water in the river was usually of fair quality. But as the population increased the supply became more and more polluted. The original pipeline, installed in the spring of 1887, took water directly out of the river from the Big Dam and piped it into the City without benefit of filtration. This unfiltered water never caused any epidemics, but dysentery was rampant every summer.

A brochure, published in 1898 to attract new residents to Loveland, touted pure water as one of Loveland's chief attractions. It pointed out, "the water, fresh from the springs and melting snow banks, is taken from the river where it emerges from mountain canyons before it is contaminated by irrigation, alkali or mining processes."

Mr. H. Mendelson, chief chemist for the sugar beet factory, did a chemical analysis of Loveland's water in October 1901. He found the water to be "nearly chemically pure." Rarely had he seen water so pure as Loveland's.

WATER TREATMENT BEGINNINGS

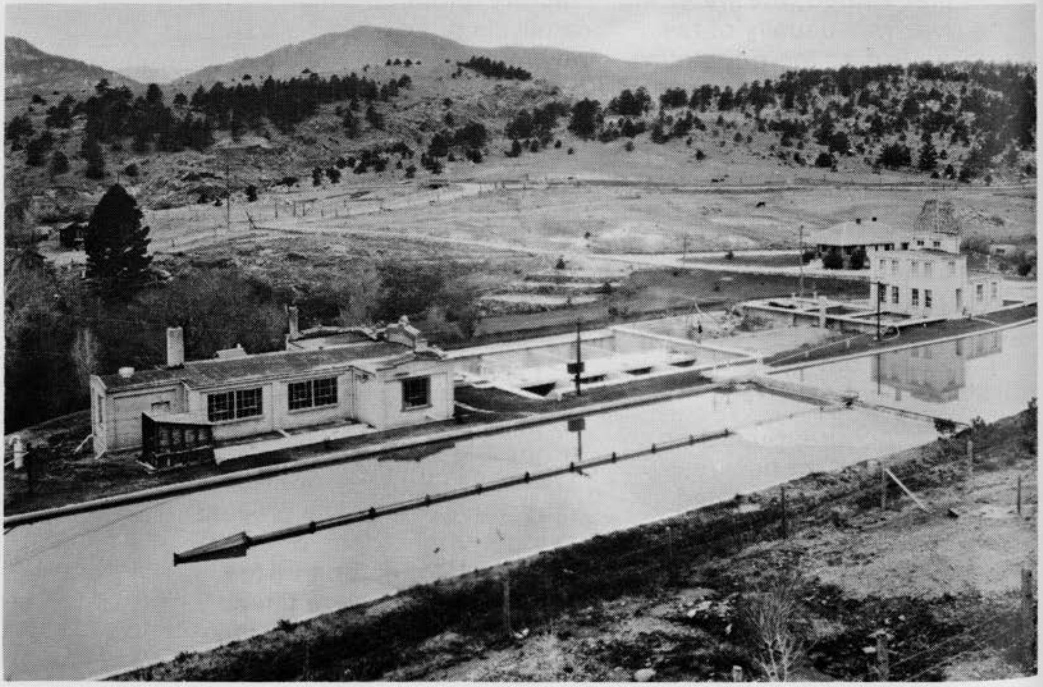
In 1902, special screens were ordered from Chicago to place over the inlet pipes at the Big Dam. The Loveland Register reported that "the screens will prevent fish and other kinds of live animals from getting inside the pipe." They were fifteen feet long and fastened onto the ends of the pipes four feet below the water.

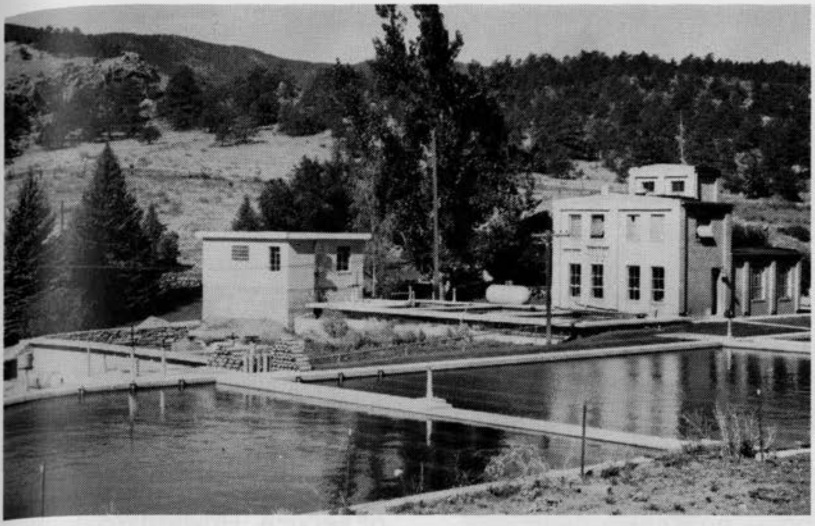
The first treatment facility for Loveland was a slow sand filter installed in 1906, at the site of the present water treatment plant. This filter consisted of about four feet of ungraded sand through which the water flowed before emptying via an underdrain. As the filter became dirty, it was shut down and the top layer of sand was removed by hand. It was a simple, but tedious process.

In 1917, another slow sand filter and a clearwater storage reservoir were added; the same year disinfection of water with hydrochloride began. Engineers recommended disinfection by ultra-violet rays in 1924, but this was too costly for the City. A building was constructed in 1924 to house six rapid sand filters (a bed of sand of uniform density) and two sedimentation basins. These additions brought the plant capacity to four and one-half million gallons per day (MGD).

The late William Davis, who retired in 1970 after almost forty years of service, recalled some of the problems he faced at the treatment plant, including

Water Treatment Plant - 1936





Water Treatment Plant - 1960

catching a bear in a trap in 1952.

Anchor ice, ice found attached to the bottom of an otherwise unfrozen stream, was always a problem as it kept water from coming through the headgate to the plant. Davis remembered it could necessitate a trip to the river every 15 minutes or so throughout a cold night to break up the ice. This inconvenience was relieved by placing a pole with three white flags spaced a foot apart into the ice that covered the intake structure. With a spotlight on them, the flags could be seen from the bedroom window of the house at the plant. As the ice built up, one by one the flags disappeared. As long as three flags were showing, it meant things were all right and Davis could rest for another hour. If only two flags were visible, it meant the headgate was clogged with ice and it was time to get up and begin work.

On Christmas Eve 1937, Davis remembered when a 24-inch concrete line from the river to the treatment plant broke. He and other employees worked through Christmas Day to restore the line, finishing the job just before the water stored in the 1.5 million gallon tank ran dry.

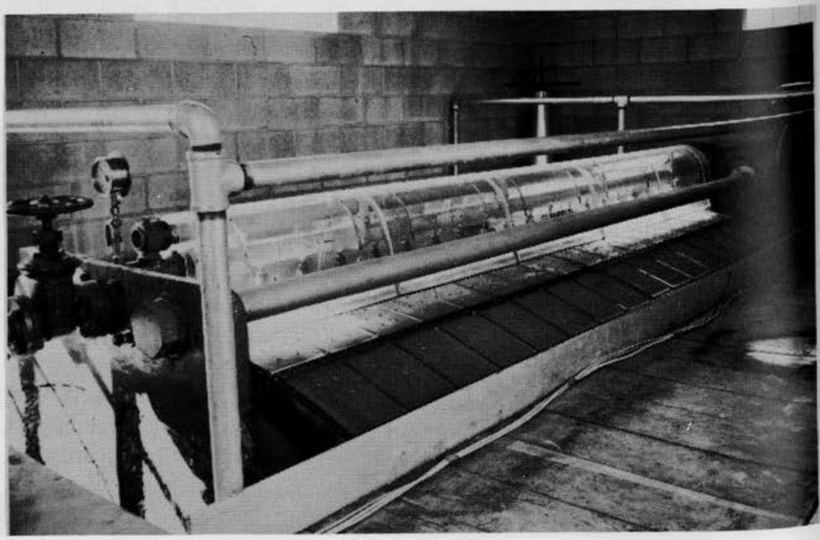
Howard Yoakum worked with Bill Davis at the plant for 18 years, beginning in 1949. Yoakum remembers how the two of them ran the plant seven days a week; Davis worked the morning shift and he worked from 2 p.m. to at

Mixed media Filters

least 10 p.m. It was a rough job – no weekends or holidays off. Yoakum, a natural handyman, had no formal training for his job at the treatment plant, but learned everything on-the-job. There was no real laboratory, so only chlorine, turbidity, and pH were tested. After almost 30 years of service, Howard Yoakum retired in 1978.

C-BT WATER ARRIVES

In 1952, as the City began to use C-BT water, algae became a problem.



Microstrainer

Installing new inlet pipe to the plant in 1959 (left and below)

Algae can cause foul taste or odor to be carried through the treatment process. In the late 1950s, carbon was used in an attempt to control this problem. To remove algae more efficiently, two microstrainers were installed, one in 1960 and a second in 1963. These machines use a rotating drum which is covered with a very fine wire mesh (over 20,000 openings per square inch). Water flows through the drums and the algae is held back and washed out with the waste water. Since C-BT water now goes into a reservoir before entering the plant, the algae problem has been reduced and the microstrainers have been eliminated.

Loveland's population growth between 1930 and 1950 was fairly slow and there were few improvements to the water treatment system. Between 1950 and 1965 Loveland's population doubled. New buildings, modern appliances, second bathrooms added to existing homes, and rising health standards created a growing demand for high quality water. In 1962, a 3 MGD treatment facility was added at the plant site. After this addition, the plant had a total of 16 rapid sand filters and a capacity of 12 MGD. Converting a sedimentation basin into two filters in 1966 brought the plant capacity to 13.5 MGD.

In 1968, the rapid sand filters began to be converted to mixed media filters. These filters process three times more water than the rapid sand filters. Mixed media filters use three different materials of increasing densities: crushed anthracite coal, filter sand, and garnet sand. The addition of two mixed media filters increased the plant capacity to 17.5 MGD.

Lyle Herman, the present plant Superintendent, remembers the spring of 1969 when the runoff caused a small flood. The water, three and one half feet over the top of the Big Dam, washed down rattlesnakes "like you wouldn't believe." They were crawling everywhere trying to escape the flood. In the following month, the plant staff killed about sixteen of them.

THE BIG THOMPSON FLOOD

On the one hundredth anniversary of the State of Colorado, July 31, 1976, a

The Big Thompson Flood of 1976 destroyed the Big Siphon

flash flood dumped nearly 12 inches of rain in less than four hours in the scenic Big Thompson canyon causing 145 deaths – and the worst natural disaster in the State's history. The Big Thompson River, 19 feet above its normal water level, destroyed 418 homes and 52 businesses.

The water supply to the City of Loveland was reduced from 18 MGD to under 2 MGD as the flood moved through the Big Thompson River system. Silt and debris blocked the intake gates; raw sewage from a broken sewer line in Estes Park briefly poured into the river and 100 feet of the 36-inch steel transmission line washed out. The Big Siphon, located across the entrance to the Big Thompson Canyon, was destroyed. In spite of all the damage, the flood restricted plant production for only five days.

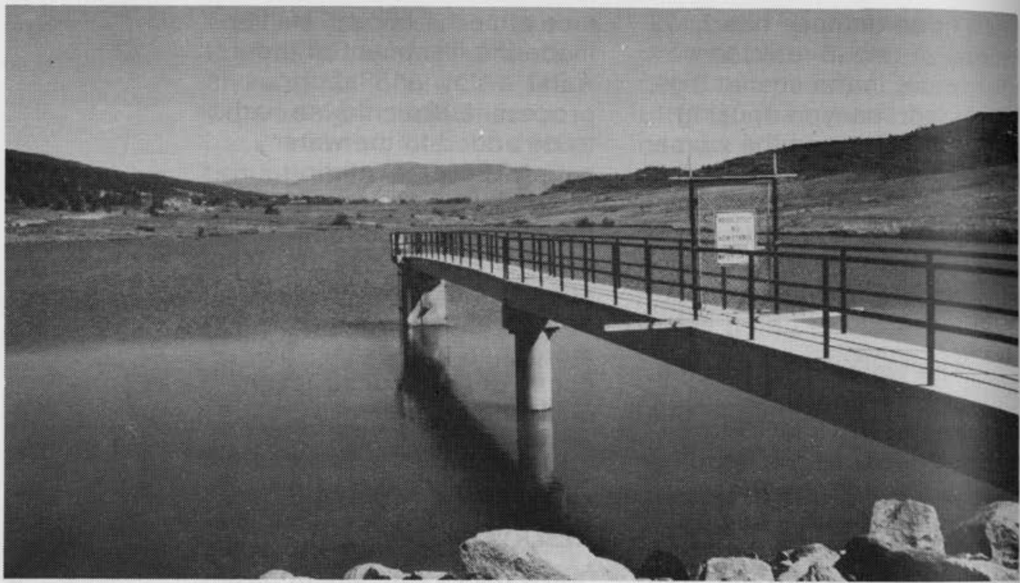
According to Superintendent Herman, during the flood the water rose 9 1/2 feet over the top of the Big Dam. Two staff members at the plant watched the entire steel truss bridge from above the Big Dam go down the river.

The turbidity of the water, a measurement of the amount of suspended particles, was high for a long time after the flood. This made the treatment of the water a slow and laborious process. Extra chlorine had to be added to the water supply. Severe watering restrictions were enacted as the plant produced only a minimal amount of water. The effects of the flood were felt at the treatment plant for more than three years because of road construction and runoff problems.

GREEN RIDGE GLADE RESERVOIR

Plans for a raw water storage reservoir were drawn up in the 1960s, but it wasn't until after the Big Thompson Flood in 1976 that construction began. Green Ridge Glade Reservoir, a 600 acre-foot reservoir located just north of the plant, was ready for use in 1979. Herman recalls the reservoir's construction and how every morning he found fresh deer tracks across the new fill they had laid the day before.

A new diversion structure was built to bring C-BT water from the Charles Hansen Feeder Canal into the reservoir. Before the reservoir existed, C-BT water was dumped into the river near the Big Siphon and taken out at the City's intake. This second source of water for



Green Ridge Glade Reservoir

the treatment plant helps ensure an adequate water supply during emergencies. The project included a pipeline from the reservoir to the plant.

If Green Ridge Glade Reservoir had existed at the time of the Big Thompson Flood, there would have been an alternate raw water supply. Need for the reservoir was again demonstrated in 1978 when the treatment plant intake structure became plugged with debris due to upstream highway reconstruction activities. Plant output was only affected for two days, but had the reservoir been in service, plant production would have been uninterrupted.

The Lawn Lake Flood in 1982 resulted in contamination of Loveland's water supply as it was being stored in Lake Estes. It was the uncontaminated water in the City's reservoir that provided the plant with sufficient water.

CHASTEEN'S GROVE

John Chasteen came from Kentucky as an Indian fighter and horse trader and stayed to homestead. He built his first log cabin beside the Big Thompson River in what came to be known as Chasteen's Grove. In 1880, Chasteen built a log-walled house above the grove. The house, which has always been lived in, has been expanded and modernized, but

The farm house at Chasteen's Grove

some of the old log walls remain. An old bunkhouse, which provided quarters for the men who worked for the original Chasteen family, and a chicken coop stood on the property for many years.

For nearly 100 years, Chasteen's Grove, located below the Big Dam and the treatment plant, was a popular spot for leisurely picnics along the river. In an interview with the Loveland Reporter-Herald in 1976, Mary Ellen Chasteen Bowman described her childhood in the house at Chasteen's Grove. Her family charged 25 cents a car to enter the picnic area. The land was sold to the City in 1947 after the death of her father, Ed Chasteen. The picnic area has been closed since the Big Thompson Flood stripped the park of its trees and grassy areas.

Howard Yoakum and his family lived in the house from from 1949 until 1967, the years he worked at the plant. He and his wife Alpha loved the old rambling house and the peaceful atmosphere of the grove.

The Bunkhouse

CHASTEEN'S GROVE WATER TREATMENT PLANT

Continual growth in Loveland led to a treatment plant expansion to 30 MGD in 1981. The expansion included an 800,000 gallon clearwell receptacle for treated water storage, sedimentation basins, and a control room with laboratory for testing water. A new

Chasteen's Grove Water Treatment Plant dedication - 1982

(Pictured L-R: Ralph Mullinix, Ray Reeb, John Connor, Don Caulkins)

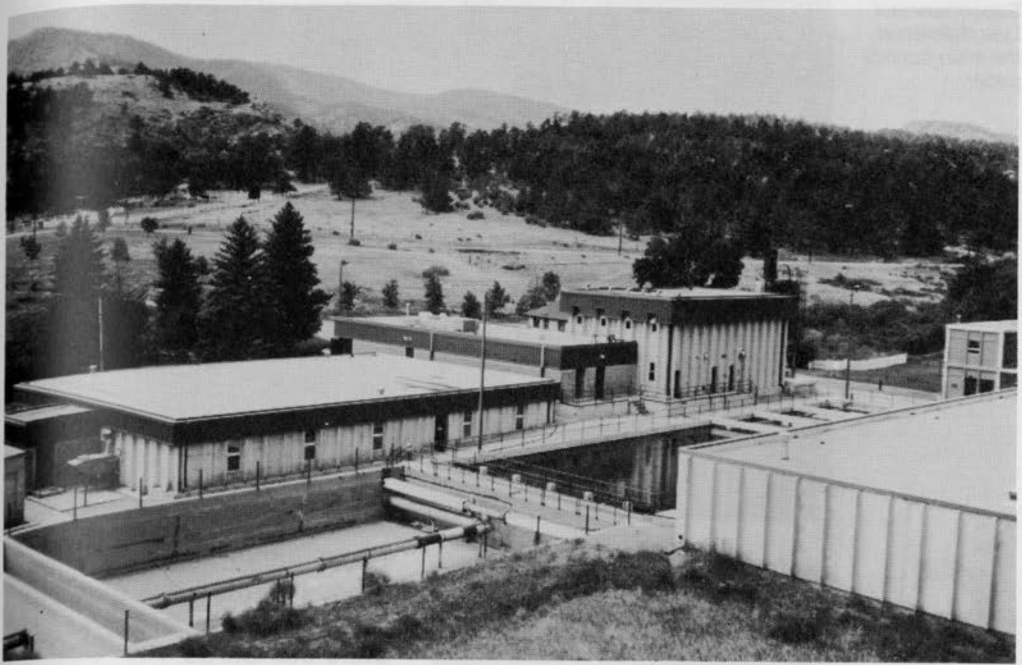
intake structure from the river was also part of this project. The plant can be expanded one more time to a capacity of 46 MGD. An open house and dedication ceremony was held at the plant on April 24, 1982, and it became known as Chasteen's Grove Water Treatment Plant.

THE TREATMENT PROCESS

Big Thompson River water enters the plant through an intake structure, which screens the water to make sure no fish or large pieces of debris are collected. The water then flows through a grit basin to settle out heavier sand particles. Potassium permanganate is added to help remove impurities, kill harmful bacteria, and destroy bad tastes and odors. Since 1952, fluoride has been added to help prevent tooth decay.

Next, the water enters the flocculation basin where big paddles stir the water. Here alum, a coagulant, is added which binds small particles into heavier, more readily settled masses. From there the water passes into sedimentation basins where it moves very slowly and allows the heavier particles to sink to the bottom and be removed. All but the most minute particles settle out here. The last step is filtration, where even microscopic particles are removed.

Water flowing out of the filters is collected in a clearwell where it is treated with



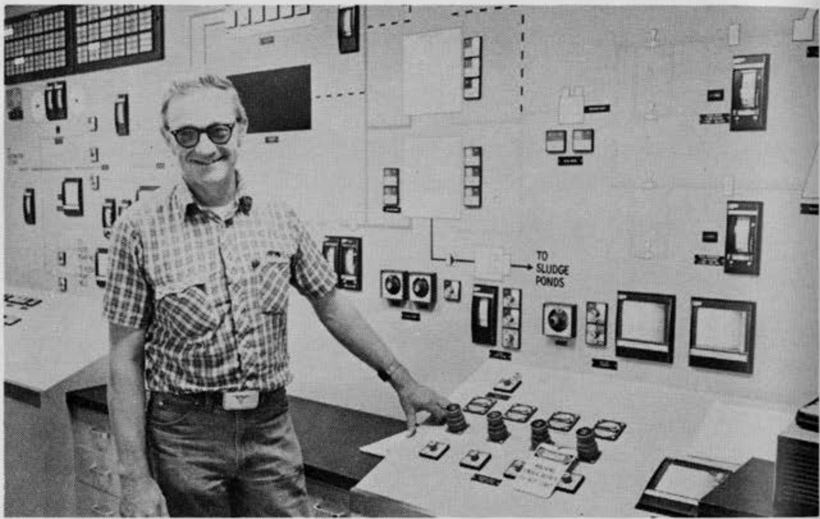
Water Treatment Plant - 1988

chlorine to prevent bacterial growth in the transmission lines.

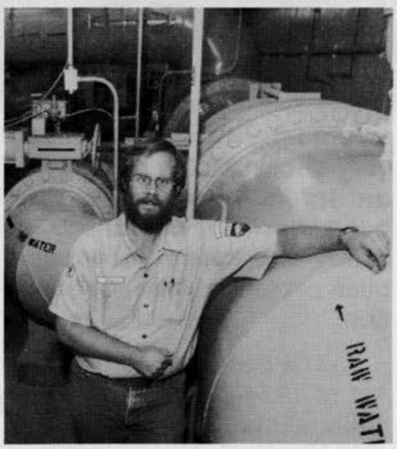
WATER QUALITY

Through a national effort that began more than 70 years ago, the United States has achieved drinking water standards that are among the most stringent in the world. The U.S. Public Health Service issued the first federal drinking water standards in 1914. Until 1974, the standards only controlled bacteria and viruses that cause cholera, typhoid and other waterborne diseases. Although the standards were very successful in curbing the spread of such disease, public concern over the safety of drinking water supplies prompted new legislation.

The Safe Drinking Water Act of 1974 (SDWA) set national standards for allowable levels of contaminants, guidelines for treating drinking water, and monitoring and reporting requirements for public water systems. An amendment to the SDWA passed in 1986 set limits on the levels of 42 chemicals and elements besides the 31 already being tested.



Superintendent Lyle Herman at the main control panel

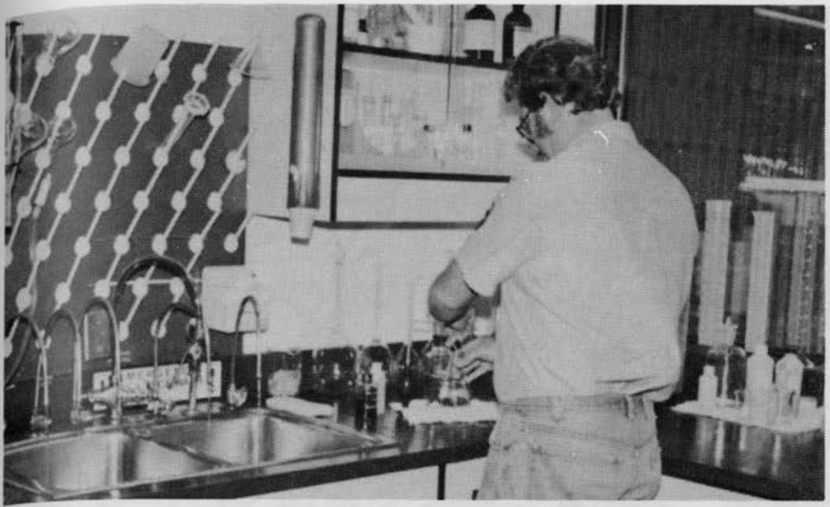


Kent Woodward in the raw water water pipe gallery

THE LABORATORY

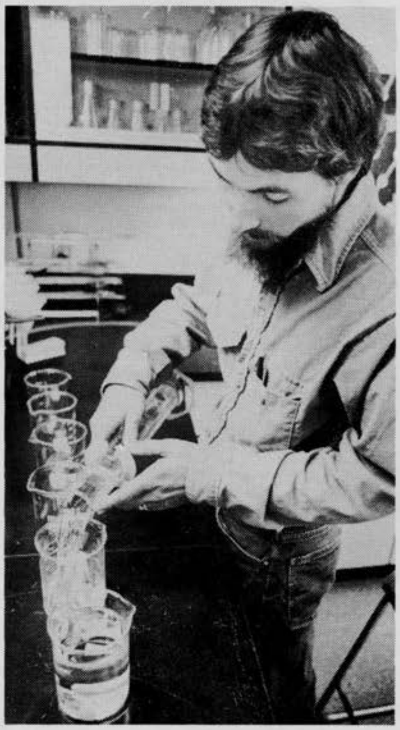
A modern, well-equipped laboratory constantly analyzes samples of treated water from the treatment plant and the distribution system. Three times a day, plant operators do 14 tests to determine the optimum chemical dosages. Loveland's treated water constantly meets, or is of higher quality than, federal and state standards.

The laboratory is certified for bacteriological testing. A laboratory technician runs 45 tests each month from water taps throughout the City, assuring that Loveland's residents are receiving water that is bacteriologically safe. Today, the laboratory uses electronic instrumentation to analyze the water. Samples are sent to the laboratory at the Colorado Department of Health for tests requiring more sophisticated instrumentation. In the past, all the tests were done by visual comparison, which was not very precise.



John Nelson in the lab

In the early 1970s, Bill Davis brought in a bucket of treated water from the plant, and four operators tested it for turbidity on a Hellige visual turbidimeter. They got four different answers. So Bill went to get another bucketful of water to try the test again. Four more tests were taken before Davis confessed that he had never dumped the original bucket of water. One operator got the same result the second time, but that still meant there were seven different numbers for turbidity. The electronic turbidimeter used today accurately produces just one number.



Lab Chemist Mike Tesar testing water

24-inch Wood Pipe

Chapter 5

WATER DISTRIBUTION

Today treated water is delivered to about 40,000 people within the Loveland area. Purified water leaves the treatment plant in transmission lines and is directed either into storage tanks or to customers. A network of water mains distributes the water to customer's taps, sprinklers, and fire hydrants.

THE WOOD PIPELINE

In 1887, Loveland's first pipeline was installed. Specifications for the pipeline included a well just above the mouth of the Home Supply Ditch at the Big Dam, a culvert across the main channel of the river, and a 6-inch wooden transmission line running nine miles to Fourth Street and Railroad Avenue.

The well was to be 6 1/2 feet below the bed of the river and not less than 6 feet square in the inside. The walls of the well were to be made with "good flat-faced rock."

The original specifications for the 6-inch pipe called for "the best quality wrought iron, lap-welded and coated with asphalt." But the Michigan Pipe Company convinced the Town Council that wood was a better material and won the construction bid.

Random lengths of bored Michigan pine logs were banded with continuous flat wrought iron to make the pipe. The exterior was tarred and wooden spigots connected the pipe lengths. The pipeline stayed in service until about 1930 when part of it was abandoned. A portion of this line remained in service until 1939.

Digging trenches for the pipeline was no easy task. The work was done by hand with picks and shovels. The trenches were eight feet deep.

The contract included twelve fire hydrants and over 10,000 feet of smaller diameter pipe. Each fire hydrant was set with a 3-foot diameter brick manhole. The final bill came to $41,400, and the pipeline was completed in August 1887.

The Committee on Water Works, overseeing the pipeline construction, reported to the Town Council in April 1887 that, "they found the work was being done in a very imperfect and unworkmanlike manner. The pipe was laid crooked and the joints were not driven close together." To assure the pipeline was put in according to specifications, the Committee employed Mr. Charles Pulliam for $60 a month to superintend the construction.

But the Town Council had different ideas and voted to hire Mr. J. L. Connors as superintendent of the project for $3 a day. In June 1887, Town Marshal David James took on additional duties as Superintendent of the Water Works, replacing Mr. Connors. James received $20 per month, in addition to his $60 a month salary.

In 1901, citizens approved a $60,000 bond issue to pay for a new pipeline to supply Loveland's sugar beet factory with water. A 12-inch continuous wood stave pipeline of Douglas fir was completed that year, from the Big Dam to Eighth Street and Lincoln Avenue.

John H. Nelson, the town surveyor, drew the plans for the pipeline. Unrolled, the plans were 14 feet in length. Three bids were submitted for the pipeline construction, and choosing the contractor was surrounded with controversy. In March 1901, the Water Works committee opened the bids at a closed meeting and awarded the contract to the highest bidder, J. E. Rhodes.

Outraged citizens convinced the Town Council to rescind that contract and award it to the lowest bidder, McCabe and Teagarden of Boulder. After being awarded the bid, the Boulder company pleaded with the Council to let them construct an iron pipeline, instead of a wooden one. It seems they had made a mistake in their bid and couldn't possibly put in a wood line for the amount bid. The third bidder, Holme & Allen, was awarded the final contract for $39,600 and constructed the line as specified.

The wood stave line consisted of boards two inches thick, five inches wide, and ten feet long. To be watertight, the tongue and groove boards were squeezed together with 5/8-inch diameter threaded bands. The bands were held in place with shoes (pieces of threaded metal with nuts that tightened). An 8-inch cast iron main carried the water the remaining distance to the factory.

W. A. Riley was awarded the contract to excavate and backfill the pipeline. He advertised for workers: laborers $1.75 a day and rock men $2.00 a day. A cook was wanted for $40.00 a month.

WOOD PIPELINE MEMORIES

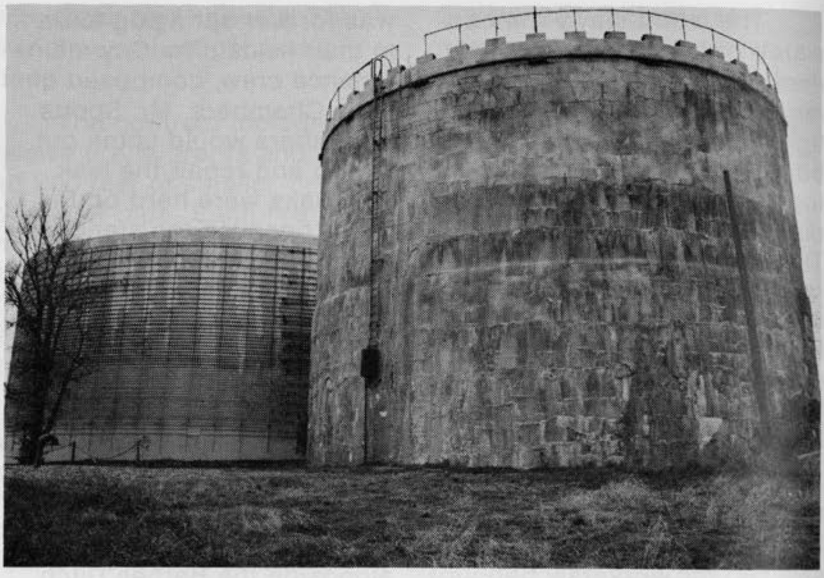
Donald C. Moss, longtime resident, remembers the 12-inch wood pipeline that crossed his father's farm (the early Rist-Benson homestead) that was rented from the Great Western Sugar Company. Mariano Medina's cabins and the Namaqua fort were in his backyard. The house had City water; its pressure powered his mother's washing machine.

Moss recalls that the wooden transmission line was forever springing leaks in their fields. The City maintenance crew, composed of Ursa Chambers, Mr. Spotts and others would come out, dig up and repair the leak. The leaks were hard on the crops because the standing water often killed the plants. The maintenance crew had to drive their vehicles across the fields to get to the leak and that also damaged crops. But no one ever complained or asked the City of Loveland for damages.

This main went across the river bottom, climbed alongside the Barnes Ditch across the pasture of Mr. Moss's grandfather Bartlow at the end of Eighth Street. The small leaks in that pasture were seldom reported and hardly ever repaired. The leaks supplied irrigation water for the pasture. The main went east across the Bartlow farm and under one corner of the house. Mr. Moss recollects one very cold winter in about 1918 when the pipeline sprang a large leak about 30 feet east of the house. The water shot up to the tops of the poplar trees surrounding the house. It froze and the weight of the ice stripped the trees of their limbs. Ice covered the house and yard.

The 12-inch wood line ran through the property on

Water tanks near Devil's Backbone (left - built in 1953, right - 1924)



Glade Road where Ted Van Dusen grew up. He recalls hauling water from the river to the house until his father figured out how to tap the line. Apparently, the Van Dusen family had free water service for a period of time.

THE LEANING TOWER OF PISA

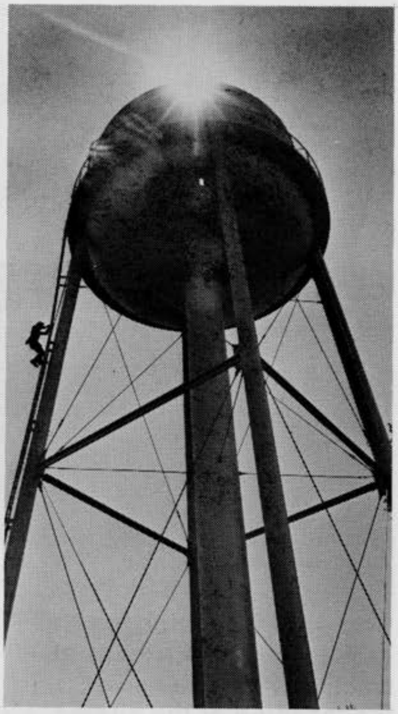
Loveland's "Leaning Tower of Pisa" was constructed in 1918 at 14th Street and Cleveland Avenue. The 70-foot high, 27-foot diameter steel-laced concrete water tank looked like a medieval tower. With a capacity of 250,000 gallons, its original purpose was to provide water pressure for the northeast section of the city. In 1925 its usefulness ended with the expansion of the treatment plant and two new transmission lines. It cost $8,000 to build the tower structure, less than the cost to demolish it in 1967 to make possible the widening of Highway 34.

In 1924, a one and one-half million gallon concrete storage tank was built on the west side of town, near the Devil's Backbone. The tank's innovative design and construction techniques generated a lot of interest. William Hewett was the designer. Once the concrete pouring began, it went on 24 hours a day until completion. After the concrete set, steel bands were tightened around the tank. It was quite an undertaking at that time. Permanently taken out of service in 1985, this tank is scheduled to be demolished.

Also in 1924, a 20-inch wood stave pipeline was installed from the water treatment plant to the new storage tank, and a 24-inch wood line was constructed from the tank to Tenth Street and Garfield Avenue. The 20-inch wood line was in service until 1981, when a 48-inch line was installed to carry the purified water to the cement tanks near the Devil's Backbone. The 24-inch wood line is still in service on Tenth Street from Colorado Avenue to Garfield Avenue.

In 1938, a 20-inch cast iron pipeline with leadite joints was laid alongside the 24-inch wood line with help from Works Progress Administration (WPA) forces. The WPA, a federal agency of the 1930s, found community improvement projects for unemployed workers. Although the wood line had very few breaks over the years, the cast-iron line with leadite joints, averaged about two breaks a year.

A four million gallon prestressed concrete storage tank was constructed in 1953 near the Devil's Backbone, adjacent to the tank built in 1924. It

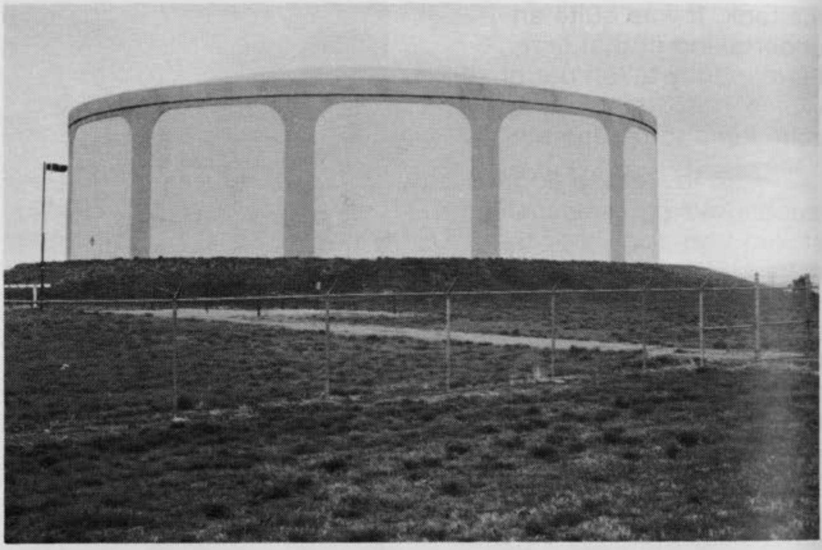


Campion water tank

leaked until 1967 when it was sealed with a rubber fillet lining. In 1963, the Chicago Bridge and Iron Company constructed a 100,000 gallon elevated steel water storage tank in Campion. Another four million gallon steel tank was built off 29th Street, just west of Wilson Avenue in 1965. Interestingly, the supported steel dome roof was fabricated on the floor of the tank and then raised into position by compressed air.

A five million gallon storage tank was built in 1983 at Taft Avenue and 42nd Street SW. Neighbors

Water storage tank at South Taft Avenue and 42nd Street SW



who originally opposed the tank later agreed it was attractive after extensive landscaping at the site.

The City's four storage tanks help to equalize pressure in the distribution system, meet peak hour demands, and provide water for fire protection. Although most of the system operates by gravity, there are four booster pump stations to provide adequate water pressure to higher areas.

Distribution system mains range in size from 4 to 36 inches and have been constructed of wood stave, cast iron, ductile iron and polyvinyl chloride (PVC). In recent years, PVC has been used extensively for 12-inch and smaller mains, while ductile iron is used for larger mains. Today there are about 500 miles of water lines in Loveland.

LEAKY PIPES

John Smit, retired foreman of the construction crew, remembers it was the City's philosophy for many years to repair water lines without shutting them off so that no one was left without water. Repairing water lines under pressure was difficult. When lines had to be shut down, customers were supplied water through hoses from other mains.

According to longtime Water Utility employees Allan

Ray Frank repairing a leak on Connecticut Avenue

Olmstead and Dean Bach, in 1963 the 20-inch cast-iron line sprang a leak where it crossed the Big Thompson River. The leak was caused by deterioration of the leadite joints. They had to dam the river and divert the water around the area where they were working. The crew worked day and night to repair the pipe. To replace the leadite, they filled the holes with jute and then caulked them with lead wool. To complete the job, a bell dresser was tightened over the joint.

Olmstead and Bach remember well the day in July 1969 when "the men walked on the moon." A homeowner was digging with a backhoe in his backyard and hit what he thought was a tree root. As water shot into the air, it didn't take him long to discover that he had put a hole in the 24-inch wood pipeline. Olmstead and Bach were on the scene soon after it happened and

Left - Dean Bach potholing to find a leak

Right - Lyle Barr repairing a water leak

ended up spending two nights there before the line was repaired.

Repairing the old wooden line was a difficult and time-consuming task. First, the bands had to be taken off, and then a rubber shield and a steel plate were positioned over the hole. Bands with shoes were wrapped around the pipe at close intervals. A special tool called a "crow's foot" was used to install a nut onto the shoe to hold the bands tight. When water was run through the line, leaks were still evident. So pieces of redwood were hammered into the holes and then broken off in splinters. As the splinters became wet and swelled, the line became watertight.

Maintaining water lines, valves, and meters in good working order is a time-consuming but important task. Crews inspect, test, and repair all the parts of the transmission system. Each year over 1,000 fire hydrants are flushed to clean sediment out of the water mains.

WATER RESTRICTIONS

It was only six years after the Water Utility was established that lawn watering regulations appeared on the books. It must have been an exceptionally dry summer in 1893, for in July the town fathers passed an ordinance dividing the town into two sections; one district watering from 5 a.m. until 1 p.m. and the other from 1 p.m. until 9 p.m. This was in effect from April to September each year with the hours reversed after three months.

Flushing a fire hydrant

The City again imposed watering restrictions on its customers during the summer of 1970. A decrease in water consumption following the restrictions was readily apparent. Until 1981, watering restrictions let customers water only every two or three days. In some years, regulations prohibited customers from watering during the hottest part of the day. The installation of water meters and the expansion of the water treatment plant allowed the restrictions to be lifted.

WATER METERS

In July 1979, the Loveland City Council approved an ordinance requiring water meters for all new construction and for existing homes when ownership changed hands. Before that time, the City only required meters for commercial accounts within the City and for all accounts served outside the City limits. Less than a year later, June 1980, the council passed another ordinance requiring meters for all water customers.

By 1981, the City was completely metered at a cost of over $3 million. The average annual water usage declined by 20 percent. Before metering, the water treatment plant's maximum day demand was 22 million gallons per day (MGD). Maximum day since metering has been 16.7 MGD. Loveland's water usage currently averages 188 gallons per capita per day (gpcd).

WATER RATES

The methods of charging for water have gone through many changes in the past 100 years. In the years before the City supplied water, an enterprising businessman charged 25 cents for a whiskey barrel of water. In 1887, the Water Utility established a flat rate, based on the type of dwelling and the number of fixtures. Customers paid the yearly fee in advance. For a residence with five rooms or less, the rate was twelve dollars. Each toilet and bathtub in the house carried an additional two dollar fee. For a barber shop or blacksmith shop, the rate was ten dollars per year. To keep one horse, cow, or other animal for private use, the fee was two dollars a year, and additional animals were only one dollar a head.

Getting customers to pay their water bills was a continual problem. In May 1892, Town Marshal Kelly was instructed to turn off water service to sixty customers who had not paid their bills. By the time twenty services had been turned off, those who had not paid were lined up at the City Clerk's office ready to pay.

In July 1901, the Town Council decided bills must be paid by everyone using the town's water, whether they were hooked up or not. This resulted in the arrest of

F. M. Brinkley, who pled guilty to using water from a hydrant. He was fined, but the fine was dismissed.

Until 1968, rates were based on a flat fee determined by fixture count. But keeping track of the number of bathrooms and toilet fixtures in homes was hard. So in July 1968, the City developed a flat rate charge per family based upon average water usage. Lot size determined the rate for lawn sprinkling. Since 1981, the monthly billing has reflected actual water use with the installation of meters. A water bill has a fixed or minimum charge and a volume or consumption charge. The volume charge assesses the same rate per thousand gallons, regardless of the amount of water used.

Installing a manhole on North Madison Avenue - 1982

Chapter 6

Wastewater Collection and Storm Drainage

As Loveland's population grew, the disposal of domestic wastes became a public problem. Early settlers used privy vaults, water closets, cesspools, and latrines to dispose of sanitary wastes. These methods drained the wastes into the soil, polluted wells, and smelled bad.

TO SEWER OR NOT

In 1893, the problem of sewage disposal in Loveland came before the Town Council. Councilman Spotts told the council that the stench from several privy vaults was a hazard to public health. The Council ordered the vaults be replaced with more sanitary means.

Controversy over installing a sewer system began in 1900, when a $5,000 bond issue was placed on the ballot. A bond issue to build an electric power plant was also to be voted on. Heated arguments were reported in the local newspapers until the April 3 election. While the Loveland Register advocated installing a sewer system, the Leader was decidedly opposed. In February, the Register stated arguments favoring the system:

"A sewerage system will benefit the health of our people. It will afford a complete drainage system for our beautiful town. Draining swamps and marshes and removing stagnant surface water has been so beneficial to any community that no one in this age questions the result."

Opponents balked at the cost, and said, "at this time there is no crying need for a sewerage system." Voters defeated the sewer bond issue, but opted for electric lights.

In February 1902, an informal vote of the citizens was conducted, and this time the outcome was in favor of constructing a sewer and drainage system. Ordinance 82 established a public sewer system on October 24, 1902. It stated, "A public sewer for sanitary drainage is a necessity. The welfare and prosperity of the town demand its immediate construction. The absence of such a sewer is a constant menace to the health of the inhabitants of the town, and a public sewer for sanitary reasons is now and hereby declared necessary."

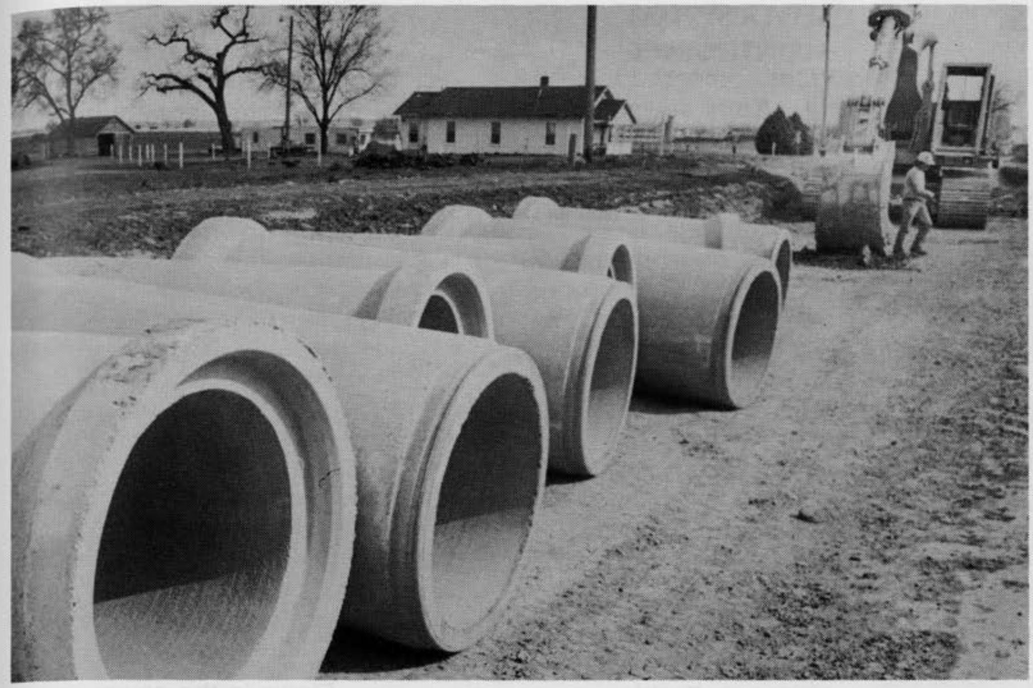
Engineer J. L. Frankeberger was hired to survey and make plans for the sewer system. Dunningan & Palmer Company was awarded the bid, and the construction was completed by February 1903. A sanitary sewer fund was created to pay the $10,230 construction fee.

Two sanitary sewer mains were constructed of vitrified clay pipe – one to serve the east side of town and one to serve the west. The east side main ran down Washington Street from the alley between Seventh and Eighth Streets, south to First Street. The line continued west on First Street to Railroad Avenue and then headed south to empty into the Big Thompson River. To serve the west side, a main was built on Garfield Street from Seventh Street south to First Street, then east to connect with the other sewer.

Beneath the sanitary sewer, an 8-inch underdrain was installed to alleviate the groundwater problem. The sewer system carried both wastes and storm runoff directly into the river. Manholes were built by hand using vitrified clay bricks and cement mortar. Some of these manholes are still in use.

The sewer main the town funded was known as the public sewer, other mains were added by district. By ordinance, sewer districts began to be established in early 1903. Funding for the district sewer lines was solely by the property owners, although the lines were owned and maintained by the town. As Loveland grew, new districts were formed, and the sewer system expanded.

Retired employee Ted Van Dusen recalls digging trenches by hand for new sewer lines in the 1930s. The



Sewer construction on North Madison Avenue - 1982

crew dug over a hundred feet of 8-foot deep trench a day. John Smit remembers the City purchasing a Barber Green ditch digger in the early 1950s. It was bought as surplus from the Army after the Japanese internment camp closed near Greeley. After its purchase, trenches were not dug by hand again. By 1955, the department had purchased a backhoe.

Most sewer lines older than 10 years were constructed of vitrified clay pipe (VCP) using cement mortar joints. For the past ten years, polyvinyl chloride pipe (PVC) has been used almost exclusively for small sewers, with reinforced concrete pipe (RCP) used for sewers larger than 12 inches in diameter. Currently, precast concrete manholes are being used in sanitary sewer construction.

Sewer lift stations have allowed sewer service to be extended to lower lying areas of new development. Thirteen lift stations now in operation lift the wastewater to a higher elevation where it can flow by gravity.

SEWER SYSTEM MAINTENANCE

Early sewer cleaning was a very unpleasant task with a tool called a rodder. A wooden rodder had three-foot sections, like a broom handle, that hooked together. It was pushed by hand into the pipe until it hit the blockage, then it took eight men to crank it to loosen the blockage. Whatever was blocking the line would come into the manhole so fast that it was hard to get out of the manhole ahead of it.

Today, sewer lines are cleaned at least once a year using two hydraulic jet cleaners. Problem areas are rodded and flushed as often as necessary.

SEWER RATES

In January 1947, customers began to be charged for their sewer service. Until that time, sewer system construction and maintenance was paid out of general City funds. The yearly rate was made part of the quarterly water bill. A private residence was charged $4.00, a restaurant $12.00, and a canning factory $16.00. Today, the sewer bill is paid monthly. The rate is determined each March based on the average amount of water a residence has used during the months of December, January and February. These months record the indoor water usage, most of which ends up going down the drain.

INFILTRATION

Loveland has a high groundwater problem in many areas as a result of snowmelt, precipitation, and poor drainage. During the irrigation season, additional water seeps out of irrigation ditches and reservoirs such as Lake Loveland, and the water table rises.

Flows in the sewer collection system fluctuate dramatically from season to season due to infiltration and inflow. Infiltration is the entrance of groundwater into the sewer system from cracked pipes, broken joints, improper connections, and leaky manholes. Inflow is the illicit discharge of surface water from rain and snowmelt into sewers from roof leaders, foundation drains, storm sewers, and catch basins. During high flow periods, large amounts of grit, sand, and silt may be carried to the wastewater plant, decreasing the plant's efficiency.

Dean Hartley and Mike Hicks laying storm drainage pipeline at Horseshoe Lake

STORM DRAINAGE

Management of storm water is new to the Water/ Wastewater Department. Until 1986, the Street Department was responsible for storm drainage and street sweeping.

The City doubled its population during the 1970s and storm runoff problems increased in frequency and intensity. The existing drainage system was inadequate, but no funds were available for improvements. The only storm drainage projects constructed were the result of flooding damage.

A manual outlining storm drainage policies and design criteria for improvements was completed in 1979. It required developers to submit a detailed drainage study of the land being developed. Drainage fees, designated for future storm drainage improvements, were also collected.

In 1982, three irrigation companies agreed to allow the City to continue to use their facilities for storm water. They stipulated that the City create a master plan for storm water improvements and provide the necessary financing. The Master Plan divided the Loveland

Bike trail along a storm drainage ditch in Fort Collins

area into 22 main drainage basins and 400 local basins. The plan included preliminary designs for many major, and some minor drainage improvements. Cost estimates were also made. The Master Plan, formally adopted by the City Council in August 1986, serves today as the guideline for storm water improvements. That same year, the criteria manual was substantially updated.

STORM WATER UTILITY

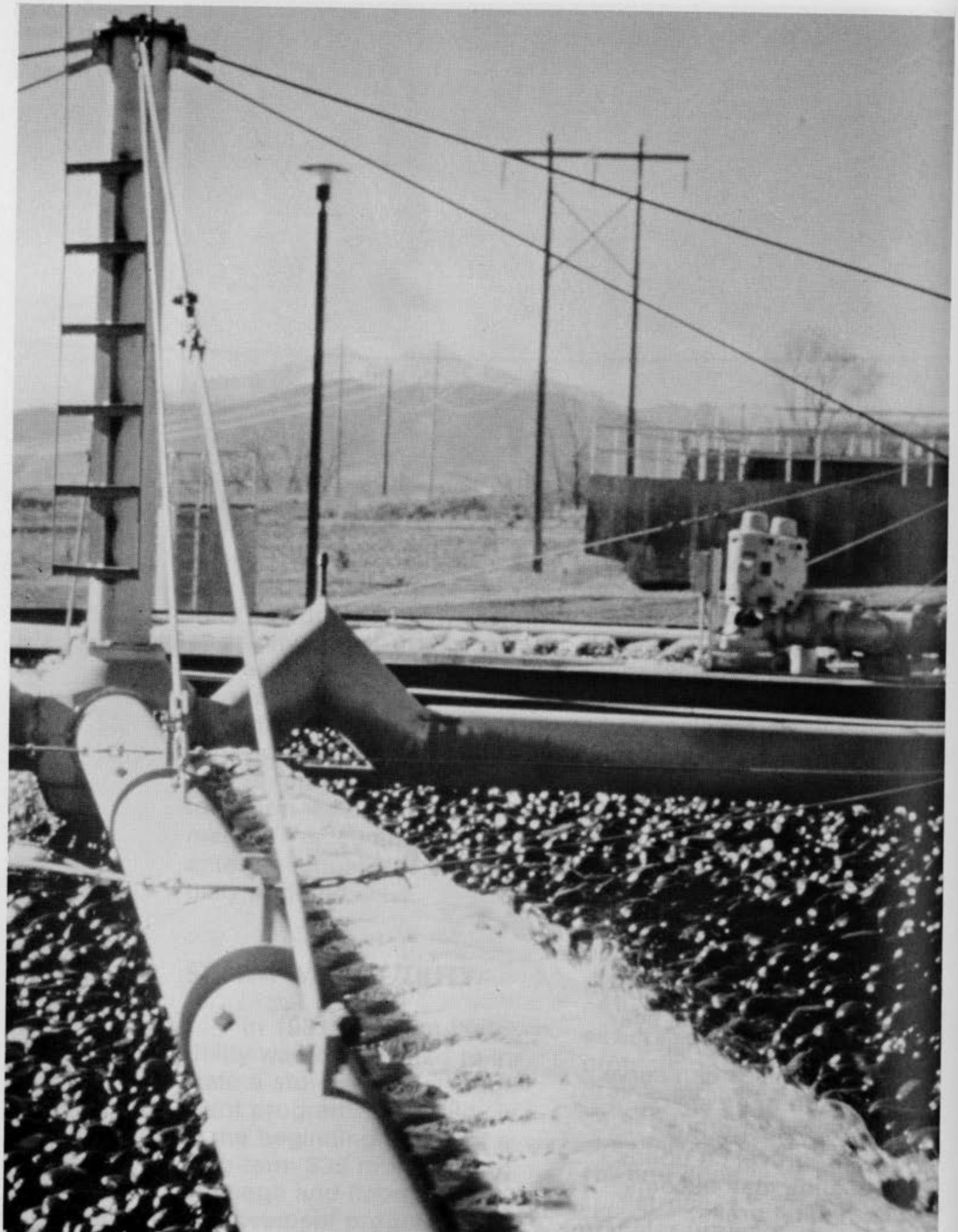
In 1987, a Storm Water Utility was established to initiate a storm water management program. The Utility is in the beginning phase of a long-term $35 million storm drainage and flood control improvement program.

The utility is funded by a monthly storm water utility fee paid by customers and based on total lot size and category. Fee categories include residential, commercial, industrial, and institutional properties. About half of the fee revenue is used for system maintenance, street sweeping, minor project improvements, and program administration. The other half is devoted to minor and major capital improvement projects. Minor projects include catch basin replacement, small storm sewer replacement, erosion protection, culverts, and drainage ditches. Regional detention facilities, floodway channels, large storm sewers, ditch crossings, and spill structures are examples of major projects.

Cleaning out a clogged storm drain

Storm water maintenance crews perform street sweeping, inlet and catch basin cleaning, street washing, storm sewer flushing, detention basin mowing, and minor construction projects.

As storm drainage improvements are made, there are several side benefits. All open channel storm water facilities (i.e. ditches, creeks, rivers) require maintenance access roads. These roads may serve as part of the Citywide hike and bike trail system. The large regional detention facilities can serve as parks and open space. The Big Thompson River floodplain, gravel pit ponds, and wetlands may become wildlife habitat areas.



Trickling filter at Boise Avenue Wastewater Treatment Plant

Chapter 7

WASTEWATER TREATMENT

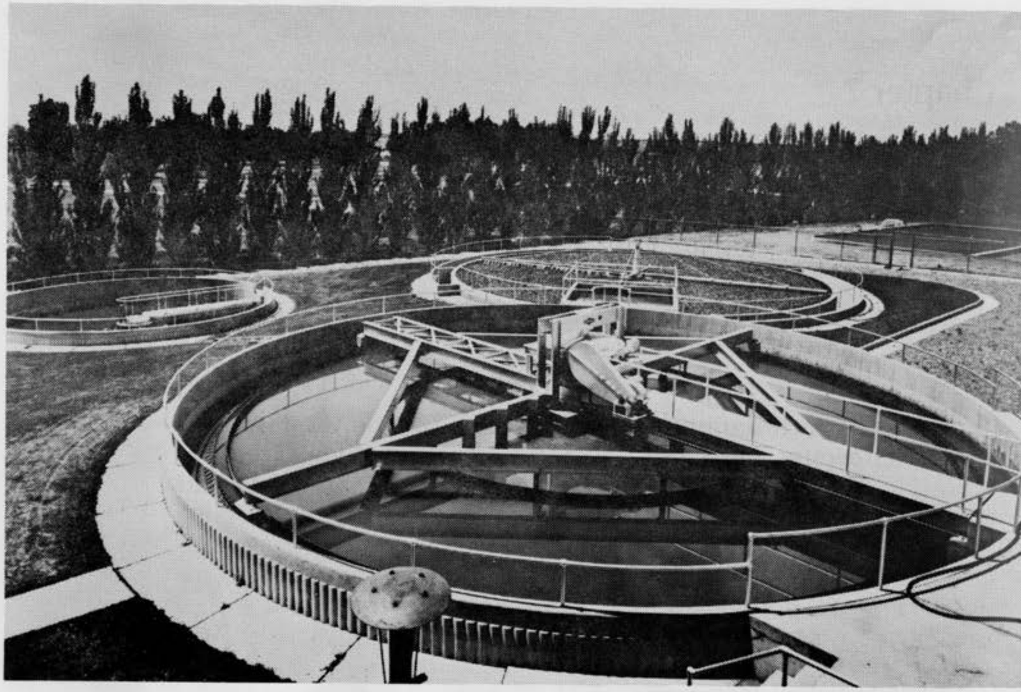
Methods for treating wastewater were explored in the late 1800s, but the process was deemed too costly for most cities. Many cities found their drinking water sources polluted with raw sewage, causing outbreaks of cholera and other epidemics. When the public became aware of water pollution dangers in the 1920s, cities began to treat their wastewater.

The first efforts emphasized primary treatment – or simply separating the solids from the liquid. Later, secondary or biological treatment was added with the development of the trickling filter and activated sludge processes. A trickling filter is a circular tank filled with stones, with windmill-like arms that rotate above the tank spraying wastewater over the stones. Organisms grow on the stones and biologically break down organic wastes contained in the wastewater. The activated sludge treatment process features the addition of air (oxygen) to help biologically purify wastes. This process continues to be the basis for treatment today.

THE IMHOFF TANK

Loveland's first wastewater treatment facility was built in 1935 as a city relief project with Public Works Administration funds and labor. The facility, treating wastewater from the east side of town, was an Imhoff tank on South Madison, just north of the Big Thompson River.

The Imhoff tank was a settling basin that separated solids and liquids into two distinct chambers. The separate chamber for solids allowed anaerobic decomposition to proceed rapidly. After the wastewater passed



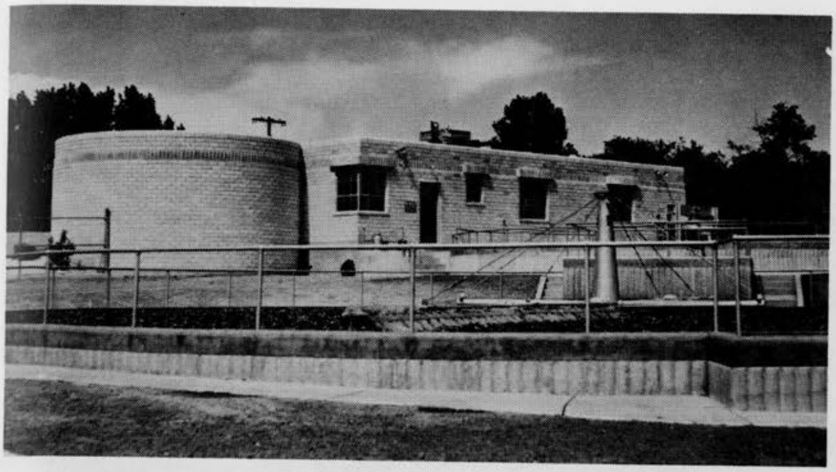
Railroad Avenue Plant - Clarifier

through a rock filter, a ditch carried it to the river. Ted Van Dusen recalls that a neighboring family, the Wards, raised worms with the effluent from the tank.

RAILROAD TREATMENT PLANT

In 1940, a large, modern treatment plant was constructed by Works Progress Administration (WPA) workers. The plant, known as the Railroad Sewage Disposal Plant, was located just north of the Fairgrounds on Third Street South and Railroad Avenue. This one MGD trickling filter and anaerobic digestion facility cost $120,000 to build. The city only contributed $35,000; the balance paid for with federal funds.

The Railroad plant was one of the first plants in Colorado to use the biological treatment method. A trickling filter, flocculator, anaerobic digester, and clarifier were built at the plant site. Frank Phillips was the first caretaker of the treatment plant for a salary of $80.00 per month. This plant was simple to operate and discharged the best effluent



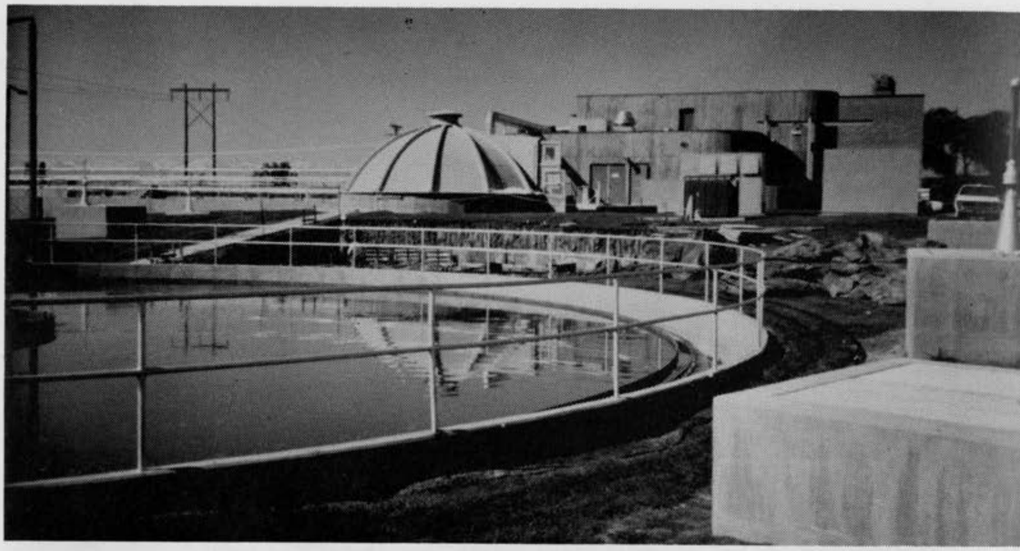
Railroad Avenue Plant - Digester

in the State during the 1950s and 1960s, according to Ted Van Dusen.

Van Dusen, who worked at Plant No.1 until it closed, recalls the steps to the basement and into the digesters were made from running boards off Model A Ford cars salvaged from a junk yard.

Both the Imhoff tank and Railroad Avenue plant were taken out of service in 1962, when a new wastewater treatment plant began operating. Ted Van Dusen remembers cleaning out the digesters for the final time and finding the bottom full of cherry pits that had come to

Railroad Avenue Plant - Sludge drying beds



Boise Avenue Plant - 1987

the plant over the years from the cherry factory.

SOUTH BOISE TREATMENT PLANT

A new three MGD wastewater treatment plant was built in 1962 on the site of an old pig farm. The trickling filter and anaerobic digestion plant, known as the Boise Avenue Treatment Plant, was built a mile east of the old plant on Boise Avenue, between the Farmer's Ditch and the Big Thompson River.

Three separate interceptor sewers (24-inch Boyd Lake, 24-inch South Eighth Street, and 33-inch Fairgrounds) converge in a manhole just north of the headworks to bring all the wastewater to the plant. The flow of wastewater into the plant varies significantly throughout the day.

Before natural gas was introduced at the plant, methane was used to heat the boilers and a waste gas burner. When the wind blew and the pilot light went out, the gas would go straight out of the plant. There was no need for an emergency alarm; the neighbors soon called to complain about the odor.

With the aid of a 75 percent EPA construction grant, the plant was expanded to a capacity of 7.7 MGD in 1977. During this construction period, the Railroad plant was temporarily reopened to

Retired Operator Jerry Ulin at the controls of the trickling filter

take some of the load off the Boise Avenue plant. It was permanently abandoned and dismantled in 1977.

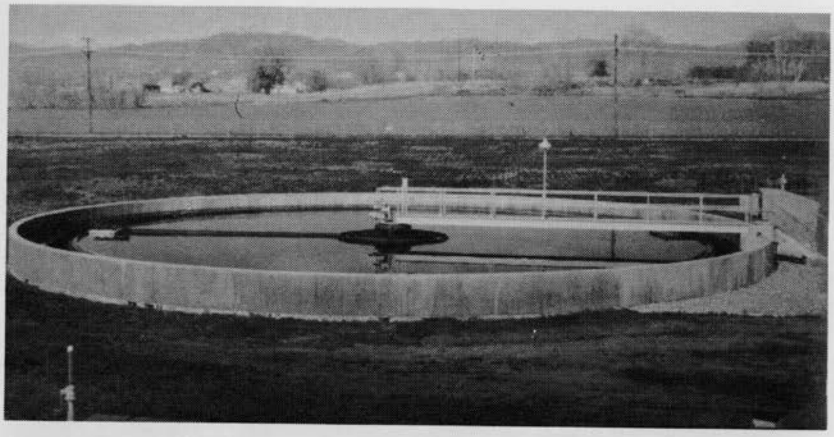
The wastewater plant underwent a $5.1 million modification and expansion between 1985 and 1987 to eliminate hydraulic problems and expand the plant's biological treatment capabilities. The sequence of the plant flow was changed to increase the plant's capacity without excessive construction costs. The revised facility can treat an average flow of eight million gallons per day.

THE PROCESS

Superintendent Johnny Tuxhorn, department employee since 1969, remembers the time when treating wastewater was regarded as a minor function of the City. Today, wastewater treatment is a complicated and important process, requiring operators to be certified in plant operations.

As wastewater enters the plant, grit and debris are removed by screening. Clarifiers then remove most of the settleable solids. In the trickling filter, organisms decompose the organic solids. The thousands of rocks in the trickling filter were taken from the Big

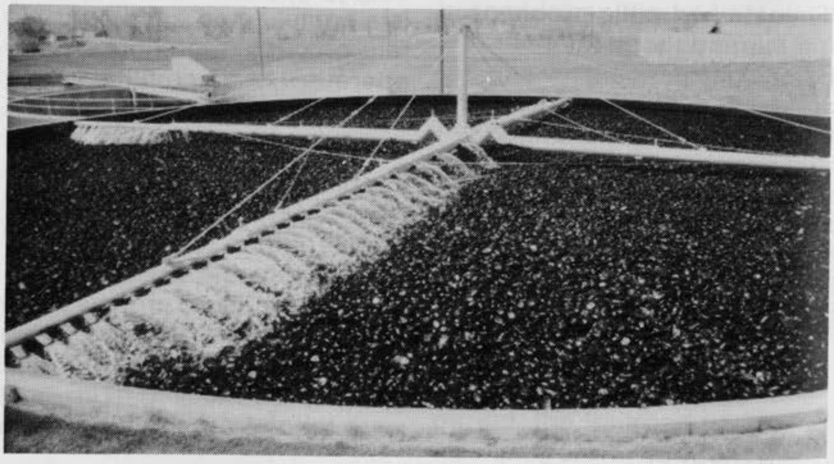
Clarifier



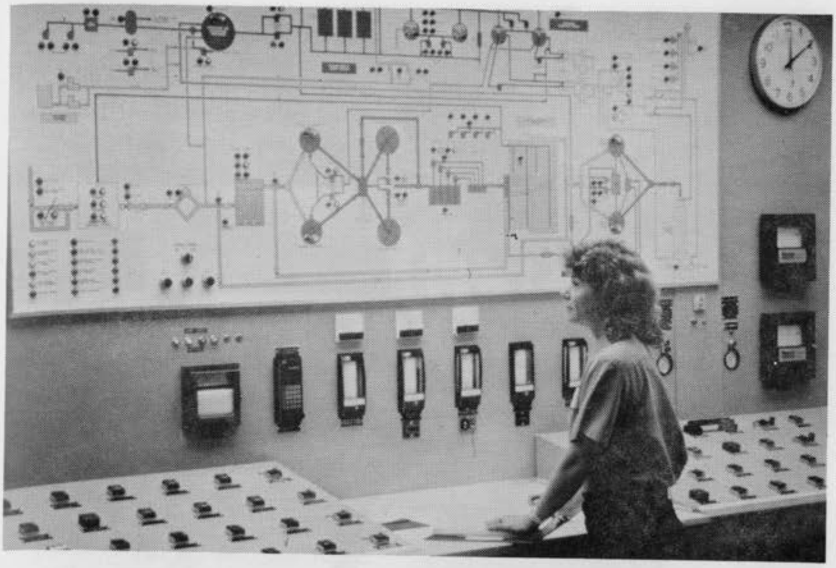
Thompson River. Two final clarifiers separate the microorganisms from the treated wastewater.

Chlorine is mixed with wastewater to kill harmful microorganisms. Sulfur dioxide is added farther downstream to dechlorinate the wastewater before it is discharged to the Big Thompson River.

Sludge is the heavy, slimy residue left as wastewater is cleaned. It consists of solids removed from the wastewater, together with water removed with the solids. Before it can be disposed, sludge must be treated. Anaerobic digesters process and biologically stabilize sludge, producing methane gas and rendering the sludge into fertilizer.



Trickling Filter



Stephanie Odell at the Control Panel

WASTEWATER LABORATORY

Even though wastewater had been treated for many years, streams and rivers in the United States were still polluted in the 1960s. In the 1970s treating wastewater became a more sophisticated science. The Federal Water Pollution Control Act amendments of 1972 and 1977 (Clean Water Act) set stringent requirements for

Superintendent Johnny Tuxhorn

Operator Jim Trotter testing at the aeration basins

wastewater returning to the nation's waterways.

In compliance with the Clean Water Act, the City was issued a National Pollutant Discharge Elimination System (NPDES) permit to discharge wastewater from the treatment plant. Wastewater testing for operational control and NPDES permit reporting takes place in a new, well-equipped laboratory. Lab chemists and technicians test for dissolved oxygen, coliform bacteria, suspended solids, and dissolved metals in the Big Thompson River two to three times a week.

Since 1986, the laboratory has used biomonitoring to determine if the effluent might be toxic to aquatic life. Ceriodaphnia (tiny water fleas) and fathead minnows are placed in containers of effluent and monitored for 48 hours. If some die, it indicates that toxins exist in the water and further testing needs to be done. So far not a single organism has died during the tests.

As a result of federal regulations, Loveland has instituted a pretreatment program for those industries that may discharge potentially toxic wastes into the City's collection system. The Water Quality Control Division of the Colorado Department of Health requires Loveland to monitor such industries and to enforce applicable pretreatment regulations.

Service Center - South Wilson Avenue and First Street

Chapter 8

THE ORGANIZATION

The Water/Wastewater Department is responsible for securing an adequate raw water supply and for providing Loveland residents with a reliable and safe supply of drinking water. The department maintains sufficient capacity to collect and treat wastewater in a manner that protects the public health. Operating a storm drainage system to keep flood damage to a minimum during extreme storms is also a duty of the department.

THE DIVISIONS

The Water/Wastewater Department has five divisions – Administration; Water Treatment; Distribution, Collection and Storm Drainage; Technical Services; and Wastewater Treatment. Since November 1986, the Administration; Distribution, Collection and Storm Drainage; and Technical Services divisions have been housed at a modern Service Center facility located at First Street and Wilson Avenue.

The Adminstration division includes administrative, technical, and engineering staff. This division is responsible for budgeting and personnel matters. Engineers review plans for water, sewer, and storm drainage improvements for new subdivisions. They also plan for new facilities, pipeline extensions, and raw water supply options. Water conservation, public relations, and a program to monitor water quality are all coordinated here.

The Water Treatment division turns raw water into high quality drinking water. Operators are on duty 24 hours a day, seven days a week with three 8-hour shifts.

Roger Douglas, Technical Services technician

The Distribution, Collection, and Storm Drainage division is responsible for maintaining and sometimes constructing water, sewer and storm drainage pipelines and facilities. This division is divided into Customer Services, Operations and Maintenance, and Storm Drainage.

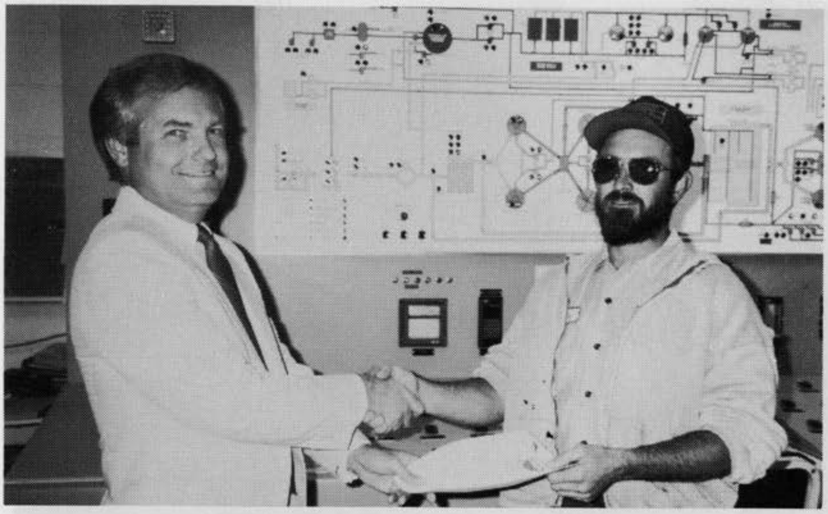
Customer Service personnel repair and maintain water meters and remote readouts, and make water and sewer taps for new services. They keep records of service lines and meters, and they provide this information to the public and Utility Billing. Customer complaints regarding water leaks and meter problems are handled here. Operations and Maintenance personnel maintain water and sewer lines, and replace or repair undersized or damaged mains. Storm Drainage personnel keep the storm drainage system operating, and construct storm drainage facilities and lines. Street sweeping, which keeps dirt and debris from entering storm drainage structures, is one of their duties.

The Technical Services division was formed in 1982 to provide expertise in the repair and maintenance of the sophisticated equipment that is needed to operate the utilities.

The Wastewater Treatment division treats wastewater to standards of quality set by the federal and state governments before discharging it. The plant runs two 8-hour shifts.

WATER BOARD

The Water Board was formed in 1981 to make policy recommendations to the City Council concerning water resource issues. Meeting monthly, the Board makes long-range plans for Loveland's future raw water supply and storage needs. The Board has nine members; two are City Council members and seven are appointed by the City Council. The term of office is four years.



Mike Hicks receives the Employee of the Quarter award from Director Ralph Mullinix

EMPLOYEE OF THE QUARTER

In 1983, an Employee of the Quarter committee was formed to recognize employees who are performing above and beyond their normal job duties. The committee is comprised of a representative from each of the five divisions. Nominations are submitted to the committee by any department employee, the committee then reviews the nominations and chooses an outstanding employee. The Director presents the certificate of award and a department pin to the Employee of the Quarter.

COMPUTERS

In 1983, the computer age arrived at the Water/Wastewater Department with the purchase of a personal computer (PC) that was shared by three engineering staff members. Demand for more computers grew after employees found many applications for Lotus 1-2-3 software. Utility accountant Jim Bruce discovered that generating the annual budget with Lotus saved labor and time. The word spread, and now all City departments use a similar budget worksheet.

Now with two word processing stations, the typewriter is nearly obsolete. Many engineering applications have found their way from slide rule and calculator to PC. More powerful computers allow the department to model water use in the entire Big Thompson

Tom Greene at the SCADA computer

River basin. A desktop publishing station produces camera-ready artwork and newsletters, doing away with cutting and pasting. This book was produced on Xerox Ventura Publisher. The treatment plants use personal computers for process analysis, record-keeping and budgeting. Each division is able to access the City's mainframe computer to review budget and expense information.

Today the department owns fourteen personal computers and a Supervisory Control and Data Acquisition (SCADA) mini-computer. The use of computers has increased productivity and improved the quality of work supplied to customers.

COMPUTER MONITORING

The SCADA computer system monitors equipment in remote water and wastewater pump stations and reservoirs. Five minutes at the printer each morning tells of any problems that need attention in the field.

Remote transmitting units (RTUs) are installed at 15 lift pump stations, four water tanks, and the water and wastewater treatment plants.

Tank levels, pump runtime activity, wetwell levels, pump-room temperatures and moisture, power and pump failures, and plant flows are all monitored by the SCADA.

Joyce Huff welcoming a guest at the Centennial Open House

CENTENNIAL CELEBRATIONS

During 1988, the Water Utility celebrated the completion of 100 years of water service to Loveland's residents. Loveland Mayor Herm Smith proclaimed the first week of May 1988 as Loveland Water Utility Centennial Week.

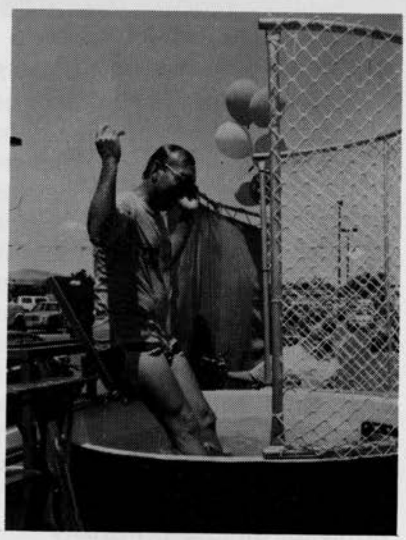
The Water Utility hosted an open house at the Service Center with displays of water memorabilia and provided tours of the water and wastewater treatment plants. Mayor Herm Smith and Water Utility Director Ralph Mullinix spoke at the commemorative ceremony attended by over 300 people.

Creative children from area schools submitted entries to the Water Utility Centennial poster and essay contests. The topic for the poster contest was "From Snowy Caps to Water Taps." The theme for the essay contest was the "importance of water in our lives." Prizes were given for the top four winners from each school.

The premiere summer event was the Water Fun Day on Saturday, July 30. Approximately 1,000 people turned out for the event, which included water games and contests for all ages. Games included a fishing pond for children, water balloon fights, a bucket relay race, and a spoon race.

Water conservation, sprinkler system, and xeriscape gardening displays were featured, as were fire engine and water safety

Displays at the open house (left and right)



Dick Leffler sliding into the dunk tank

demonstrations. A highlight of the day was watching various city officials being dunked into the cold water of a dunking machine. At three tosses for a dollar, money was raised and contributed to the Parks and Recreation Department for development of the hike and bike trail.

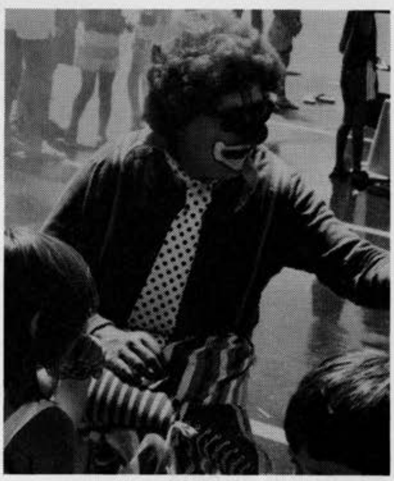
Technical Service employees constructed a brass water sprayer with a big sign on top publicizing the Water Department. The sprayer has been used at numerous local running races to cool down runners. It also cooled participants at the Water Fun Day.

"Loveland in the Mainstream" is the title of a video produced as a department overview. The video is shown to organizations to promote community awareness of the many aspects of the department. Junior and senior high school students see the video for educational purposes, and for a view of careers in the water and

Willy's Washboard Jamboree and his following

wastewater industry. Businesses considering locating in Loveland can learn about the department's water supply and modern treatment facilities.

A time capsule will be buried by the front door of the Service Center with a copy of this history. After the capsule is buried, a huge boulder moved from the water treatment plant will sit over the capsule. A brass plaque with information about opening the capsule in twenty-five years will be attached to the rock.



Steve "Chuckles the Clown" Case

Fountain at Loveland's Civic Center - 1989

EPILOGUE

Water from the Big Thompson River meant life to the early settlers. Water provided the foundation for Loveland to grow and flourish. Loveland has been transformed from a dry, treeless expanse of grassy plains to a land of lakes and cottonwoods, green lawns and fertile fields. We have come a long way since drinking water flowed in ditches along the streets.

The Water Utility has improved and modified the water service to Loveland residents many times over the years. Managing our current water supplies and developing new sources will ensure good drinking water for the years ahead. As the Big Thompson River flows on, so the Water Utility will continue to meet the challenges of the future with creativity and innovation.

Present Administration

City Council

Herman Smith, Mayor
Patricia Farnham, Mayor Pro Tem
Roger Bates
Keith Baugh
Conrad Budde Jr.
Ivan Engelhardt
Beverly Hall
James Peterson
Walter Walkowicz

City Manager

Mike Rock

Water/Wastewater Department

Administration

Ralph Mullinix, Director
Joe Bocson, Construction Inspector
Jim Bruce, Utility Accountant
Colleen Cameron, Administrative Clerk
Don Carlson, Storm Water Engineer
Laurie D'Audney, Engineering Technician
Debbie Davis, Word Processor
Thomas Greene, Associate Engineer
Kent Harbert, Water/Wastewater Engineer
Larry Howard, Water Resource Engineer
Joyce Huff, Administrative Assistant
Richard Leffler, Chief Engineer
Stephanie Odell, Pretreatment Coordinator
Todd Rogers, Operations Manager

Distribution and Collection

Rod Robey, Superintendent
Dean Bach, Crew Supervisor
Lyle Barr, Equipment Operator
David Bongers, Meter Technician
Jenni Broz, Clerk
Clyde Campbell, Crew Supervisor
Terry Corman, Equipment Operator
Ray Frank, Heavy Equipment Operator
Mary Futrell, Clerk

Walter Garcia, Utility Worker
Gary Graham, Heavy Equipment Operator
Dean Hartley, Crew Supervisor
Philip Hepler, Equipment Operator
Mike Hicks, Heavy Equipment Operator
Jim Kennedy, Equipment Operator
Bill Kilmer, Equipment Operator
Mike Morgan, Utility Worker
Al Olmstead, Meter Technician
Roger Schaffer, Equipment Operator
Franz Severin, Equipment Operator
Dean Stumpf, Equipment Operator
Dick Weinland, Equipment Operator

Technical Services

Ed Russell, Superintendent
Roger Douglas, Technician
Harry Hammers, Machinist
Regis Petrich, Control Specialist
John Pickett, Technician
John Schlueter, Technician
Don Sorensen, Technician
Gene Wild, Technician

Wastewater Treatment

Johnny Tuxhorn, Superintendent
Mitch Berner, Maintenance Worker
Steve Case, Operator
Janice DeFosse, Laboratory Technician
Patrick Kline, Operator
Michael McCrary, Operator
Cindi Rutledge, Operator
Mike Tesar, Laboratory Chemist
Bill Thomas, Operator
James Trotter, Operator

Water Treatment

Lyle Herman, Superintendent
Cheryl Barricklow, Operator
William Fullbright, Operator
Paul Gilbert, Operator
John Nelson, Laboratory Technician
John Perrine, Operator
Art Watson, Operator
Kent Woodward, Operator

Bibliography

Books

Ahlbrandt, Arlene and Stieben, Kathryn, ed., The History of Larimer County, Colorado, Vol. 2. Dallas, Texas: Curtis Media Corp., 1987

Ball, Clara, ed., Loveland-Big Thompson Valley. Big Thompson Valley Centennial Commission, Inc., 1975

Brown, Florence B., The Story of Loveland. Loveland: Loveland Savings and Loan Assoc., 1969

Christensen, Erin and Ukockis, Gail, Challenge to Build: A History of Public Works & APWA in Colorado. Fort Collins: Citizen Printing, 1987

Christensen, Erin and Waddell, Karen, How the Waste was Won: A Century of Wastewater Service in Fort Collins. City of Fort Collins, 1988

Cotten, Don, ed., The Big Thompson Flood. Lubbock, Texas: C.F. Boone, 1976

Dunning, Harold Marion, Over Hill and Vale (3 vol.). Boulder: Johnson Publishing Co., 1956-1971

Gates, Zethyl, Mariano Medina. Boulder: Johnson Publishing,1981

Hartman, Bill, A Century of Remarkable Progess. Greeley: The Greeley and Loveland Irrigation Company, 1981

Jessen, Kenneth, Thompson Valley Tales. Colorado Springs: Century One Press, 1984

Judkins, Grant, ed., Big Thompson Disaster. Loveland: Lithographic Press, 1977

McComb, David, Big Thompson: Profile of a Natural Disaster. Boulder: Pruett Publishing Co., 1980

Morris, Andrew J., ed., The History of Larimer County, Colorado Vol. 1. Dallas, Texas: Curtis Media Corp., 1985

Nortier, Molly and Smith, Michael, From Bucket to Basin: 100 Years of Water Service. City of Fort Collins, 1982

Smith, Eugene, Pioneer Ethic. Boulder: Johnson Publishing Co., 1951

Watrous, Ansel, History of Larimer County. Fort Collins: Courier Printing & Publishing, 1911

Brochures and Reports

Barkley, J. R., "Northern Colorado Water Conservancy District," 1974

Black & Veatch, "Infiltration/Inflow Analysis," 1982

Bureau of Reclamation, "Colorado-Big Thompson Project," 1984

CDM, "Drought Study - Phases 1 & 2," 1986-7

CH2M Hill, "Annual Report," 1987

City of Loveland, "Loveland Water Dept.: Its Past, Present and Future," 1968

Davis, Bill, "Filter Plant Notes" and "Loveland Water Supply," 1968

Dallemand, Elbert and Hammond, Lynn, "Water Study for Loveland, Colorado," 1971

Herman, Lyle, "Recollections of the Water Treatment Plant," 1988

Home Supply Ditch & Reservoir Company, "Water - Colorado's Most Precious Asset," 1986

League of Women Voters, "Colorado Water," 1975

Landmark Engineering, "Wastewater Treatment Facilities," 1988

M & I Engineering, "Water Treatment Plant and Transmission Line Analysis," Sept. 1977

Moss, Donald, "Some Reflections on Associations with the Loveland Water Dept.," 1988

NCWCD, "Waternews - 50th Anniversary Edition," 1987

NCWCD Municipal Subdistrict, "Windy Gap Project," 1985

NHPQ, "Facilities Plan for Wastewater Treatment," July 1974

NHPQ, "Wastewater Treatment Facilities," 1977

Tipton, R. J. & Assoc. "Report on Water System," Dec. 1951

Newspapers

The Leader
Loveland Daily Reporter-Herald
Loveland Register
Loveland Reporter

Loveland City Clerk Files

City Council Minutes
City Ordinances

Loveland Library Files

History
Ordinances
Water Supply

Interviews

John Smit
Ted Van Dusen
Howard Yoakum

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p. 21, 22: Northern Colorado Water Conservancy District
p. 32: Loveland Reporter-Herald
p. 35 (upper & lower): Howard Yoakum
p. 38 (upper & lower): Loveland Reporter-Herald
p. 39(lower), 40, 45, 52, 55, 59: Loveland Reporter-Herald
p. 60, 64, 66 (upper & lower), 67(upper): Landmark Engineering
p. 67(lower): Loveland Reporter-Herald
p. 70: Loveland Museum and Gallery
p. 75, 76(upper right): Julie Schlegel, Hach Company
p. 78: Loveland Museum and Gallery

Printing

Royal Craft Printing: Loveland, Colorado

LIST OF ATTENDEES

1.	ADAMCZYK, BOB	SR. CIVIL ENG.	CITY OF COLO. SPGS. P.U.
2.	ANDUSS, LYNN	PROJECT MANAGER	COLORADO STATE UNIVERSITY
3.	APPLEHANS, RUSS	PROJECT ENGINEER	ROCKY FLATS
4.	BAKEMAN, KEITH	DAM SAFETY ENG.	U.S. FOREST SERVICE
5.	BARKER, PAUL	PROJECT ENGINEER	RESOURCE CONSULTANTS
6.	BARTA, GARY	SUP. WTR. RES. ENG.	DIV. OF WTR RES. DSB
7.	BARTLE, RUTH		BARTLE'S LAKES
8.	BASSETT, DIANA		RISKPLAN
9	BASTIAN, THOMAS	CHIEF, PROJ. SEC.	VA MED CTR./FT. LOGAN CEM.
10.	BAUCOM, BENNIE	WTR. SYS. OPER. SUPT.	CITY OF COLORADO SPGS.
11.	BECKER, HARY	LOLINE DITCH RIDER	HENRYLYN IRR. DIST.
12.	BEIN, TOM		LOVELAND LAKE & DITCH
13.	BENNETT, BILL	PRESIDENT	HIWAN SERVICE CORP.
14.	BENNETT, DON	SOURCE OF SUP. SUPVSR.	CITY OF AURORA
15.	BETTS, HOWARD	VICE PRESIDENT	HARRIS PARK WTR. & SAN.
16.	BEVILACQUA, ALBERT	CHIEF, DAMS & STRUCTURES	U.S. FISH & WILDLIFE
17.	BOLINGER, STEVE	DIRECTOR	FT. MORGAN RES. & IRR. CO.
18.	BRASFIELD, JERRY	CHIEF ENGINEER	CRYSTAL PARK CHRISTIAN COM.
19.	BRUNTZ, LARRY	MAINTENANCE	BIJOU IRR. DIST. & CO.
20.	BUSSONE, PAUL	WTR. RES. ENGINEER	WRIGTH WTR. ENG.
21.	CALLIHAN, LARRY	MANAGER OF PARKS	FOOTHILLS MET. REC./PARK
22.	COE, DOUGLAS	GENERAL ENGINEER	U.S. DEPT. OF ENERGY
23.	COLA, MIKE	WTR. RES. ENG.	DIV. WTR. RES. DSB
24.	CORDSEN, J.R.	MAINTENANCE SUPERVISOR	GLACIER LKE. PROPERTY
25.	DANIELSON, JERIS	STATE ENGINEER	STATE OF COLORADO
26.	DAVISON, MARK		SELF
27.	DEAN, TIMOTHY	HORSECREEK LAKE TENDER	HENRYLYN IRR. DIST.
28.	DEGRANT, MIKE	DEVELOPMENT MANAGER	VINTAGE COMPANIES
29.	DEGRAVE, LOUIS	SR. WTR. RES. ENG.	DIV. WTR. RES. DSB
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31.	DICKEY, JAMES	GENERAL MANAGER	LEFT HAND WATER SUPPLY CO.
32.	DINGERSON, SHIRLEY		BARTLE'S LAKES
33.	DODD, ALUA		LEFT HAND DITCH CO.
34.	EDWARDSON, MONTE	SUPT. WATER SUPPLY	CONSOLIDATED MUTUAL
35.	EFFINGER, JOHN	PRESIDENT	DEWEESE DYE D & R CO.
36.	EGGLESTON, PHIL	ASST. TO JOHN FETCHER	U. YAMPA WTR. CONS. DIST.
37.	EHLER FARMS	PRESIDENT/OWNER	FARMERS HIGHLINE
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46.	FISHER, LAURIE	DISTRICT CONSERVATIONIST	SOIL CONSERVATION SERVICE
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69.	HARBERT, JEFF	SUPERINTENDENT	CACHE LA POUDRE RES. CO.
70.	HARRIS, WILLIAM "RED"	EMERG. MGT. SPECIALIST	U.S. ARMY CORPS OF ENG.
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73.	HEIM, DAVID		ROCKY MTN. ARSENAL
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76.	HEITMAN, RON		CITY OF THORNTON
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102.	KELLY, MICHAEL	CHIEF, CEMRO-ED-GE	U.S. ARMY CRPS. ENG.OMAHA
103.	KLEIN, JAMES		LOWER LATHAM RESERVOIR
104.	KLEUHESSELINK, SCOTT	CAMP RANGER	PIKES PK. COUNCIL BOY SCOUTS
105.	KLINGENMEIER, MARG		SELF AND HUSBAND
106.	KLOEWER, KEN	DITCH RIDER	CITY OF ENGLEWOOD
107.	KOGER, MICHAEL	CONST. ISNP. ENG. TECHN	URBAN DRAINAGE & FLOOD CTRL.
108.	KOLEBER, MARK	WTR. RES. ENG.	CITY OF THORNTON

109.	KRALICEK, DALE	MGR. W/W ENGINEERING	CITY OF NORTHGLENN
110.	KRAUS, JULIE	WTR. RES. ENG.	DENVER WATER DEPT.
111.	LAIHO, DOUGLAS	PRINCIPAL	HYDRO. CONS. ENG.
112.	LAWSON, KEN	OPERATIONS SUPERVISOR	JEFERSON COUNTY AIRPORT
113.	LAWTON, RICH	SR. ENV. ENG.	ROCKWELL INTL.
114.	LEASE, DON	ASST. SUPT. GOLF COURSE	HYLAND HILLS PARK & REC.
115.	LEE, CHIN	SR. WTR. RES. ENG.	DIV. WTR. RES. DSB
116.	LEWIS, SALLY	SR. WTR. RES. ENG.	DIV. WTR. RES. DSB
117.	LOVELL, LYNN	AG. ENG.	USDA SCS
118.	LYNCH, CHARLES	FOREMAN	NORTH STERLING IRR. CO.
119.	MCCLUNG, STAN	DITCH RIDER/RES/ CARETAKER	CITY OF ENGLEWOOD
120.	MCCOY, GEORGE	WTR. RES. ENG. II	CITY OF GREELEY
121.	MCCORMICK, BILL	SUPT.	CITY OF ENGLEWOOD
122.	MCDONALD, THOMAS	PRO. ENG.	PUBLIC SERVICE CO.
123.	MCGOVERN, LEON	PLANT CIVIL/STRUCT. MGR.	ROCKWELL INTERNATIONAL
124.	MCINTYRE, BILL	SR. WTR. RES. ENG.	DIV. WTR. RES. DSB
125.	MCKAY, CHARLES	OWNER	SMART RESERVOIR
126.	MCKELVIE, DAVE	CIVIL ENGINEER C	COLO. DIV. OF WILDLIFE
127.	MCLAUGHLIN, TERRY	DAM SAFETY OFFICER	U.S. FISH & WILDLIFE
128.	MACLEOD, BOB	MAINTENANCE SPEC. III	CITY OF AURORA
129.	MAGNUSON, TERRI	ENGINEER	LEFT HAND WATER SUPPLY CO.
130.	MARSH, DENNIS	DIRECTOR	N. POUDRE IRR. CO.
131.	MARSHALL, ANN	MANAGER	FOUNTAIN MUTUAL IRR. CO.
132.	MASTRIONI, LONNIE	ASST. SUPT.	HIGHLAND
133.	MAYO, DAN	RAW WATER TECH.	CITY OF BROOMFIELD
134.	MELLEMA, GREGORY	CIVIL ENGINEER	U.S. ARMY CORPS ENG.
135.	MERRITT, CHARLES	WTR. RES. ENG.	N.M. STATE ENG. OFFICE
136.	MICHEL, ALEX	SECTY./MGR.	NORTH STERLING IRR. DIST.
137.	MIGHELL, ED	EXEC. VICE PRESIDENT	TIPTON & KALMBACH, INC.
138.	MILBRANDT, TOM	ASST. STATE CONST. ENG.	SOIL CONS. SERVICE
139.	MILLER, DENNIS	SR. WTR. RES. ENG.	DIV. WTR. RES. DSB
140.	MILLER, DENNIS		N. COLO. WTR. CONS. DIST.
141.	MITCHELL, MIKE		N. COLO. WTR. CONS. DIST.
142.	MITCHELL, JOHN	TRUSTEE	WILLIAM V. HODGES
143.	MOLER, BILL	PROJECT ENG.	MORRISON-KNUDSEN ENG.
144.	MONTOYA, MANUEL	TECHNICIAN	FARMERS RES. & IRR. CO.
145.	MOYER, ED	GEOLOGIST	COLOWYO COAL CO.
146.	MUNNS, NANCY	MGR. W/W ENG.	CITY OF NORTHGLENN
147.	MURTAUGH, ROBERT	SUPT. OF GROUNDS	PERRY PARK COUNTRY CLUB
148.	MYERS, JAMES	SUPT./SECTY.	S. SIDE IRR. RES. CO.
149.	NEIMAN, WAYNE	CARETAKER	PREWITT RESERVOIR
150.	NELSON, JAMES	SR. CIVIL ENG.	COLO. DIV. OF WILDLIFE
151.	NELSON, LAVERN	OWNER	NELSON ENGINEERS
152.	NELSON, MIKE	PROPERTY CHAIRMAN	PIKES PK. COUNCIL BOY SCOUTS
153.	NELSON, TOM	DRAIN. PLAN. ENG.	CITY & CTY. OF DENVER
154.	NEWLON, GLENN	AREA CIVIL ENG.	USDA SCS
155.	NILSSON, DON	ASST. TOWN ENG.	TOWN OF BRECKENRIDGE
156.	NOBLE, HOWARD	PROFESSIONAL ENGINEER	PUBLIC SERVICE OF COLORADO
157.	OBERING, ROLAND	PARTNER, CONS. CIVIL ENG.	OBERING, WURTH, & ASSOC.
158.	OBERMEYER, JIM	MGR. CIVIL/GEO. ENG.	WOODWARD-CLYDE CONS.
159.	O'HARA, ROGER "BUD"	DIV. MGR. WTR. RES.	BD. WTR. WRKS. PUEBLO, CO.
160.	OLSON, NORVAL	CIVIL ENG. B	COLO. DIV. OF WILDLIFE
161.	OTSUKA, KISH	CHAIRMAN	SEDGWICK SANDS DRAW
162.	PALLMAN, BILL	CIVIL ENG. A	COLO. DIV. OF WILDLIFE

163.	PARSONS, STEVE	HYDROLOGIST	U.S. OFFICE SURFACE MIN.
164.	PATTERSON, JIM		TALBERT CORP.
165.	PAYSON, ELIOT	VICE PRESIDENT	LOWER BOWLES CO.
166.	PEARSON, ALAN	CHIEF	DIV. WTR. RES. DSB
167.	PECK, BRADLY	1053 DITCH RIDER	HENRYLYN IRR. DIST.
168.	PEREZ, GREGORY	CIVIL ENG. ASST.	SCS
169.	PERKINS, RICK		LARIMER CTY. EMERG. PLAN.
170.	PERSHIN, JOE	CHIEF OPERATOR	CITY OF ENGLEWOOD
171.	PRICE, JOHNNY	WATER DEPT. SUPT.	CITY OF MANITOU SPRINGS
172.	RABAN, EDWARDO	CIVIL ENG. C	COLO. DIV. OF WILDLIFE
173.	RANISATE, ROY	ENGIENERING TECHNICIAN	U.S. ARMY CORPS OF ENG.
174.	RHODES, RANDY	WATER COORDINATOR	PUBLIC SERVICE COMPANY
175.	RINGLE, ALLEN	SUPERINTENDENT	LAKE HENRY & LAKE MEREDITH
176.	RIVERA, BOB	CHIEF ENGINEER	CONSOLIDATED MUTUAL WTR. CO.
177.	ROBERTS, GARY	WTR. SYSTEM SUP.	TOWN OF BRECKENRIDGE
178.	ROBLER, ROBERT	SUP. RESOURCE ENG.	CITY OF COLORADO SPGS.
179.	ROLLINS, KEN	PRESIDENT	ROCKY MTN. CONSULTANTS
180.	ROESSER, JOE	TOWN ENGINEER	TOWN OF BRECKENRIDGE
181.	ROSCOE, JOHN	DIRECTOR	LOOKOUT MTN. WATER DIST.
182.	ROSILLON, JEANIE	DESIGNED REVIEW ENGINEER	JEFFERSON COUTNTY
183.	ROSSI, DAVE	STAFF ENG.	VA MED. CTR./FT. LOGAN CEM.
184.	RUSSELL, GARY	GROUNDS SUPT.	HIWAN GOLF CLUB
185.	RYBUS, MARK	DIR. OF WTR. & SEWER	CITY OF GREELEY
186.	SABOL, GEORGE	CONS. ENG.	HYDROLOGY/HYDRAULICS
187.	SADAR, ORVILLE	BOARD MEMBER	OLIGARCHY IRR. CO.
188.	SAMPLEY, KEN	SR. CIVIL ENG.	CITY OF COLO. SPGS. P.U.
189.	SCHAEFFER, RICK	DITCH RIDER	CONS. HOME SUPP. DITCH
190.	SCHAFFNER, ANDREA	CARETAKER	YAMCOLO, STILLWTR, GARDNER
191.	SCHLAGEL, PHIL		LOWER LATHAM RESERVOIR
192.	SCHLAGEL, ROBERT	PRESIDENT	HIGHLAND DITCH CO.
193.	SCHMIDT, L. STEPHEN	PROJECT MANAGER	ROCKY MTN. CONSULTANTS
194.	SCHULTZ, GERALD	GENERAL MANAGER	EVERGREEN METRO DIST.
195.	SELNER, CRAIG	ASST. DITCH RIDER	BERGEN DITCH & RES.
196.	SHIELDS, JOSEPH	CIVIL ENG.	U.S. ARMY CORPS OF ENG.
197.	SHULL, HAROLD	DAM TENDER	JACKSON LAKE RES. & IRR. CO.
198.	SILHASEK, BOB	DTCH SUPT.	LOUDEN DITCH CO.
199.	SKEEN, TIMOTHY	CIVIL ENG.	U.S. ARMY CORPS OF ENG.
200.	SMART, TYLER	PROJECT MANAGER	GREINER INC.
201.	SMITH, TIM	CHIEF OPERATOR	CITY OF STEAMBOAT SPRINGS
202.	SORENSON, PATRIC	CITY ENGINEER	CITY OF LAFAYETTE
203.	SPANN, STEVE	SUP. WTR. RES. ENG.	DIV. WTR. RES. DSB
204.	STANDARD, JERRY	MAINT. SUP.	TOWN OF MONUMENT
205.	STEEN, GARY	PROJECT ENGINEER	MONUMENT VALLEY ENGINEERS
206.	STEWART, KEVIN	PROJECT ENGINEER	URBAN DRAINAGE & FLOOD
207.	STEWART, SAM	MAINTENANCE	JEFFERSON COUNTY AIRPORT
208.	STIEBEN, ROBERT	PRESIDENT	N. POUDRE IRR. CO.
209.	STORE, TOM	FACILITY MAINT./CONST. SUP.	FOOTHILLS MET. REC./PARK
210.	STRICKLIN, ROBERT	DAM TENDER	SPRING VALLYE PRPTY. OWNERS
211.	STRIETELMEIER, DAN	WATER RES. ANALYST	CITY OF WESTMINSTER
212.	STRUTTON, KENNETH	BR. CHIEF, WASTE WTR.	U.S.A.F. ACADEMY
213.	SULLIVAN, JAMES	WATER RES. ENG.	CITY OF ARVADA
214.	SULLIVAN, MIKE	MANAGER-OPERATIONS	CITY OF THORNTON
215.	SWARTS, LARRY	BOX ELDER DITCH RIDER	HENRYLYN IRR. DIST.
216.	SWOBODA, ALBERT	HYDRO. ENG.	COE-OMAHA

217.	TAYLOR, JOHN	PARKS SUPT.	HIGHLAND
218.	TCZAP, ANDREW	SECTION MANAGER	HDR ENGINEERING, INC.
219.	TEAGUE, RICHARD	MANAGER	WOODS LAKE RANCH
220.	TOMPKINS, KEITH	ASST. REGIONAL ENG.	U.S. FOREST SERVICE
221.	TUCKER, ROBERT	DAM & R.O.W. SPEC.	CITY OF AURORA
222.	VAN SCIVER, JOHN	SUP. WTR. RES. ENG.	DIV. WTR. RES. DSB
223.	WAGNER, HERBERT	KEENE DITCH RIDER	HENRYLYN IRR. DIST.
224.	WAGNER, PHILIP	PROSPECT LAKE TENDER	HENRYLYN IRR. DIST.
225.	WAMSLEY, DONALD	PRESIDENT	WAMSLEY CATTLE CO., INC.
226.	WALTHALL, BRENT	MAINTENANCE INSPECTOR	URBAN DRAINAGE & FLOOD CTL.
227.	WEBER, KEITH	SUPT.	BIJOU IRR. DIST. & CO.
228.	WENTWORTH, WAYNE	ENGINEER	LEFT HAND WATER SUPPLY CO.
229.	WELTON, WALLY	VICE PRESIDENT ENG. & OPER.	CONSOLIDATED MUTUAL WTR. CO.
230.	WESTMORE, RICHARD	SENIOR ENGINEER	HARZA ENGINEERING CO.
231.	WILKES, GLADE	HYDRAULIC ENGINEER	SOIL CONSERVATION SERVICE
232.	WILLIAMS, NED	PROJECT COORDINATOR	P.O.B. UTILITY DEPT.
233.	WOODWARD, BART	SUPT.	RIVERSIDE RES. & LAND CO.
234.	WOOLRIDGE, JIM	SUPT. OF DISTRICTS	N. COLO. WTR. CONS. DIST.
235.	YOUNG, ARTHUR	RES. MAINTENANCE	BIJOU IRR. DIST. & CO.
236.	ZANCANELLA, TOM	WTR. RES. ENG.	WRIGHT WTR. ENG.

SAFETY CONSIDERATIONS RELATED TO THE CONSTRUCTION OF EARTHFILL DAMS

by
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Prepared for:
Eastern Slope Dam Safety Workshop

Sponsored by:
Office of the Colorado State Engineer

Introduction

The most important aspects of earth dam construction effecting the safety of the structure are related to excavation, foundation treatment and preparation, and initial placement of fill, especially against the foundation and adjacent to concrete structures. Most earth dam failures not related to overtopping by floods, are caused by internal erosion (piping) of the embankment or foundation at or near the contact of the dam with the foundation or at the interface with concrete structures. It is impossible, at the time of design, to predict exactly the foundation conditions that might be revealed during construction, no matter how thorough the geotechnical investigation. The drawings and specifications can only give broad guidelines as to how to deal with foundation problems. It is extremely important, therefore, that an engineer, experienced in dam foundations, be on site at the time the foundation is uncovered, with the authority and ability to make sound engineering decisions in a timely manner. Incorrect decisions during construction can potentially have a catastrophic effect on dam safety in spite of the most conscientious design effort. The following is a discussion of some important construction considerations for the foundations of earthfill dams.

Excavation

Excavation is generally classified into four categories as illustrated in Figures 1 and 2, and described as follows:

- **Common**. Defined as soil or loose materials that can be moved with the blade of a Cat D-8 dozer.

- **Ripping**. Consolidated material or weathered rock that can be loosened with a single shank ripper attached to a D-8 dozer.

- **Rock Excavation.** Requires blasting.

- **Careful Excavation.** Includes hand excavation, "dental excavation" of seams and holes, and "careful blasting".

Generally, excavated materials are either placed directly in the dam, stockpiled, or wasted according to their classification. The excavation itself has little impact on dam safety until final grade is reached. At that point extreme care must be taken not to disturb the subgrade to be left in place. In soil foundations, this is usually done by leaving about six inches of material in place above grade until just before fill placement, at which time it is removed and treated. Ripping is also stopped at a safe distance above grade and the remaining material removed by hand. Careful excavation techniques are demonstrated in Figure 2. Careful blasting procedures are employed for foundation surfaces in rock. For horizontal or sloping surfaces up to 45 degrees, this consists of closely spaced lightly loaded holes, with little or no subdrilling, detonated with delays in order to reduce the charge per delay. For surfaces steeper than 45 degrees careful blasting is defined as closely spaced parallel holes detonated simultaneously, either prior to blasting the remainder of the rock to be excavated (presplitting) or on the last delay of the final shot (cushion blasting). Overhangs or linear steps in rock foundations over a few feet in height should be laid back to a slope no steeper than 70 degrees by careful blasting techniques. Abrupt changes in slope should not exceed 30 degrees.

The objective at the end of excavation is to leave an undisturbed foundation ready for initial cleanup.

Foundation Treatment and Preparation

Foundation treatment and preparation shown in Figure 3, usually consists of an initial cleanup in the area of the impervious core contact by means of light mechanical equipment, hand removal of loose material and in the case of rock excavation, light blowing with air. A detailed geologic map of the foundation should be made at this time with special attention to the orientation of open joints, faults, and zones of highly weathered rock. This mapping serves as a basis for defining the type and extent of foundation treatment required and will, in the case of rock foundations, allow grout holes to be oriented in the most favorable inclination and direction to intercept the maximum number of open joints.

Impervious cutoffs in dam foundations in soil, such as chemical grout curtains, or slurry and diaphragm walls are usually well defined by design but require constant adjustments in the field during construction. Likewise, techniques for consolidating foundations such as dynamic deep compaction and compaction grouting necessitate good common sense decision making in the field during execution in order to be successful.

Grouting of rock foundations usually consists of a line or more of deep holes drilled parallel to each other in a single plane to form a curtain. In weak or weathered rock foundations it is sometimes necessary to construct a grout cap of concrete in order to seat the holes. The holes are usually angled to intercept important open joints. The objective of the grout curtain is to cut off seepage through the deep rock foundation. Consolidation or blanket grouting consists of a pattern of shallow grout holes covering the foundation surface. These holes are usually individually oriented to intercept important open joints exposed at the surface. The objective of consolidation grouting is to enhance stability and reduce deformation of the near surface rock and to plug any open avenues to migration of fine core material into the foundation. Grouting requires a great deal of field supervision and experience in order to determine hole spacing, mix propc 'tions, and pressures. Any pockets of loose soil or highly weathered zones in the rock should be removed by hand excavation. Open joints and weathered shear zones should be cleaned to a depth at least two times their width. Cavities and cracks excavated in this manner should be backfilled with "dental concrete". Dental concrete can also be poured behind formed surfaces to eliminate overhangs.

After foundation treatment is complete, final cleanup and foundation preparation should be done. In soil foundations, this usually consists of removing the protective layer of soil, moisture conditioning the material to its optimum water content, and then compacting the surface so as to attain a density equivalent to that specified for the overlying fill. In rock foundations, the surface should be thoroughly cleaned with air and water jets. All surface water seepage from springs should be controlled, isolated, and removed from exposed areas of the foundation. In some foundations it is necessary to protect weathered rock from drying and slaking by spraying with asphaltic emulsion or application of slush grout. Sometimes for sound rock it is also advisable to seal surface cracks and minor irregularities with slush grout applied with buckets and brooms. It is often a good idea to construct a properly designed blind filter in select locations between the impervious core and the downstream side of the cutoff trench in order to avoid the migration of fine core material into the rock.

In rock foundations impervious core placement should be started immediately after final cleanup and foundation surface preparation. The fill material should be placed against a moist rock surface or onto the slush grouted surface before it has a chance to dry and crack. The initial lift of core material should be placed a little wet of optimum moisture content so that it will squeeze into minor irregularities in the rock surface. The first lift should be carefully compacted with hand operated tampers in confined areas or rubber tired equipment so as not to damage the foundation. Extreme care should be used when placing up against concrete structures to avoid segregation of coarse material against the structure and to assure that it is well compacted.

Once the embankment is off the foundation, the quality of the fill can be controlled on a routine basis by inspectors backed by a soils laboratory. Quality control during placement should consist of visual inspection to assure that embankment materials are being placed in the proper place, to the thickness specified, at the correct moisture content and rolled with the specified number of passes. In-place density and moisture tests should be taken at a predetermined frequency to assure that proper compaction is achieved.

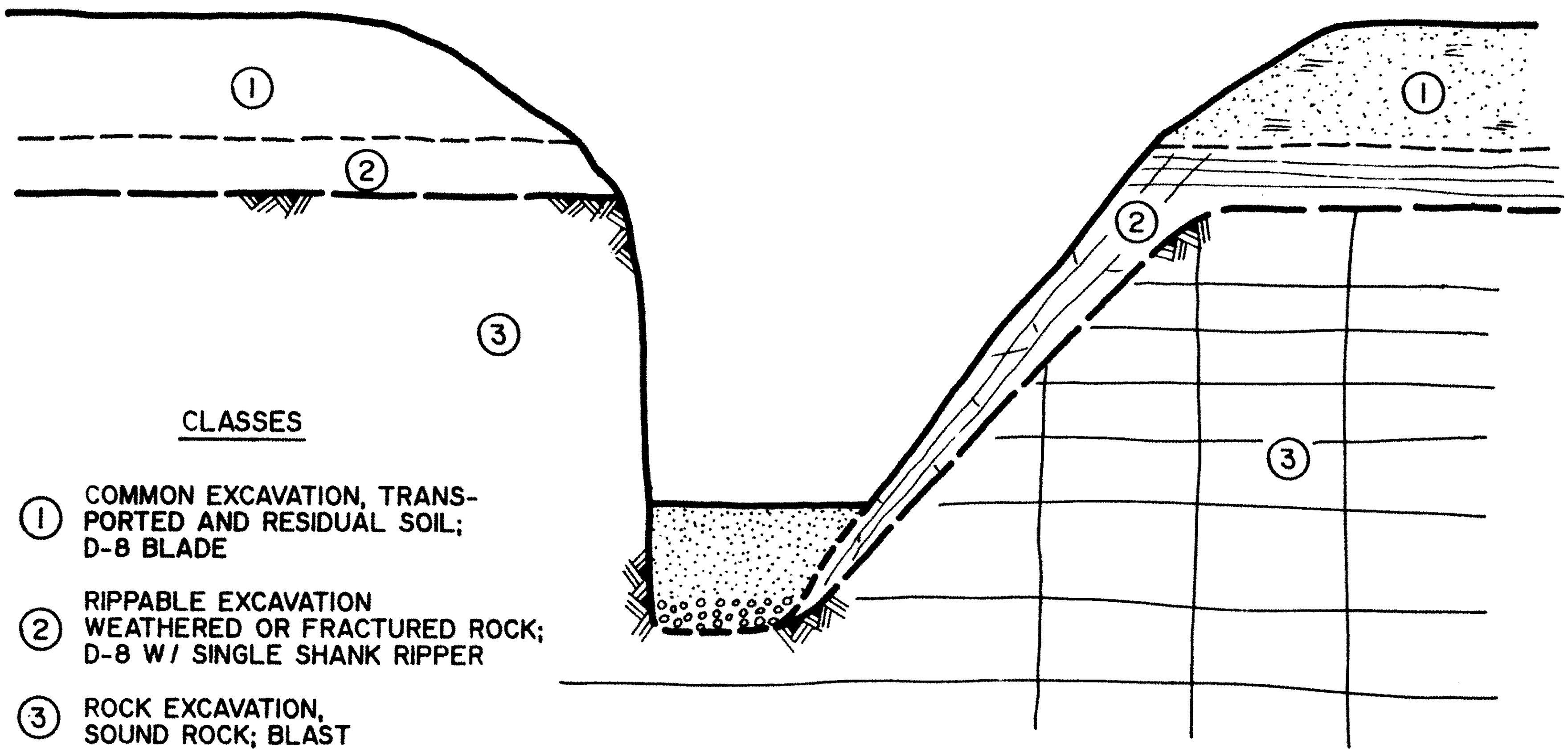
Conclusion

The construction procedures described above usually play a small part in the overall schedule and cost of dam construction but careful attention to detail during the execution of these activities can mean the difference between a safe and maintenance free dam and the potential for catastrophic failure.

References

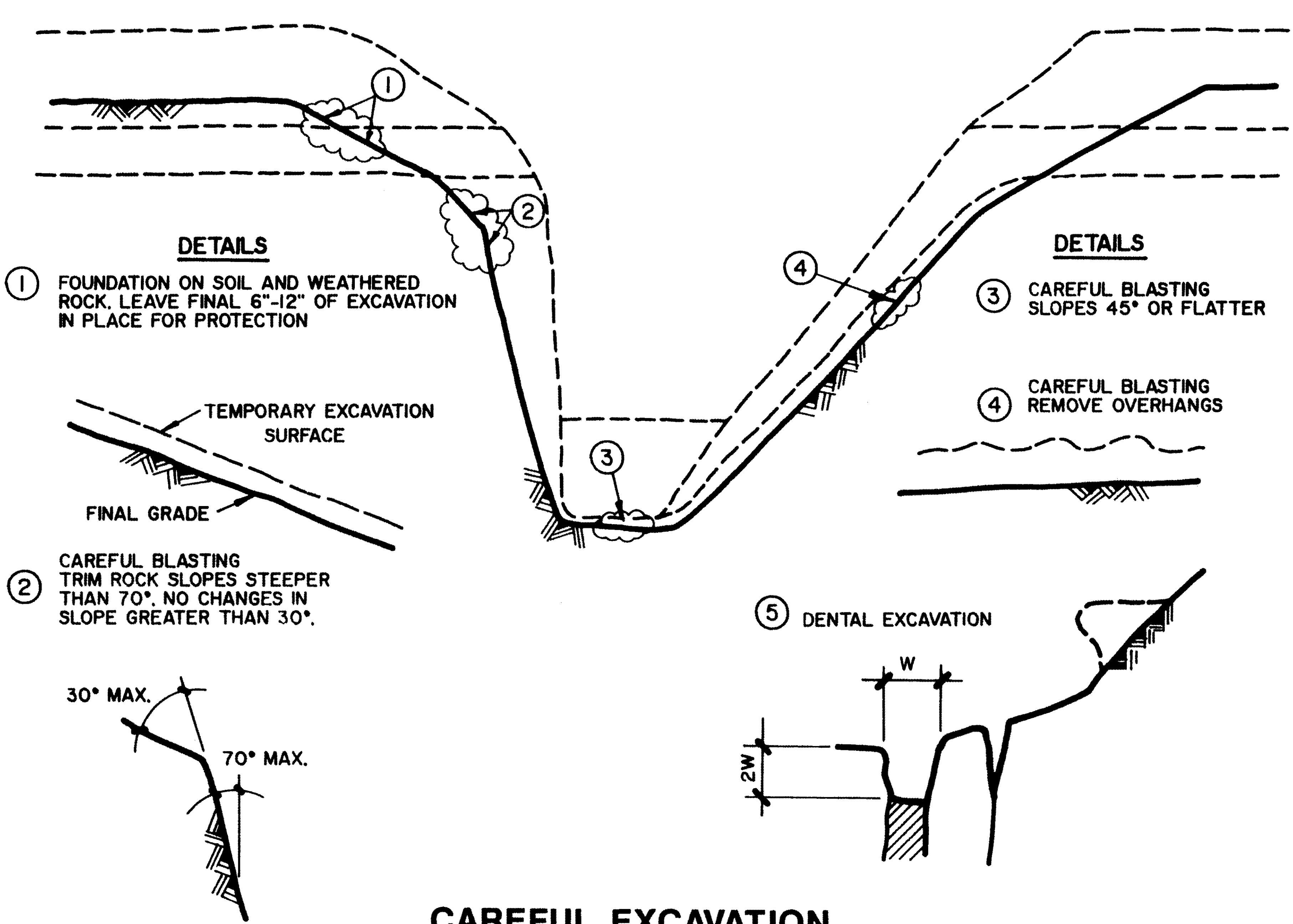
1. _____, 1977, Design of Small Dams, United States Department of Interior, Bureau of Reclamation.

2. Sherard, J. L. et al, 1963, Earth and Rockfill Dams, Wiley.



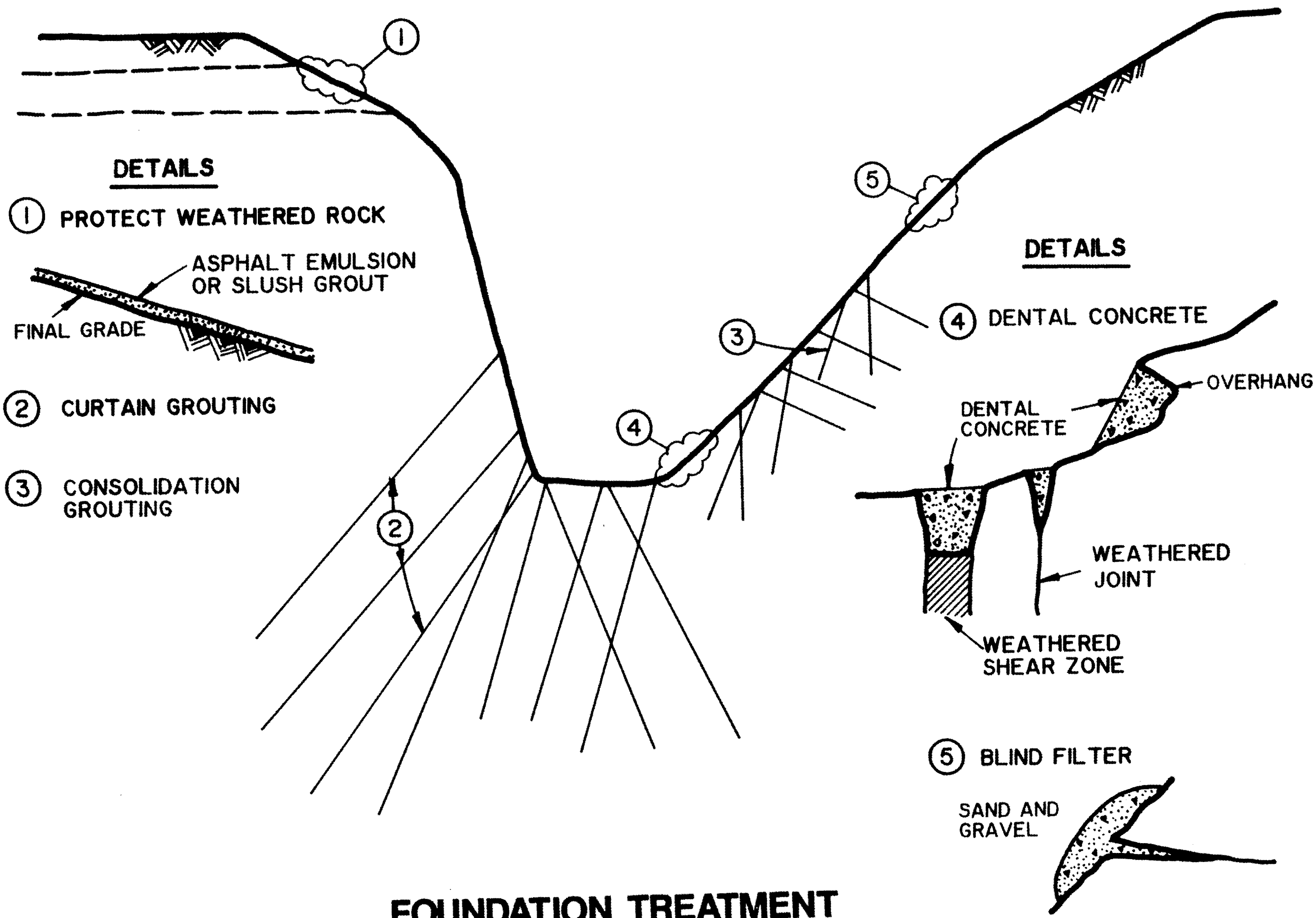
EXCAVATION

Figure 1



CAREFUL EXCAVATION

Figure 2



FOUNDATION TREATMENT

FIGURE 3

Stanford Place 3, Suite 1000
4582 South Ulster Street Parkway
Denver, Colorado 80237
(303) 694-2770
Telex 501285 (WOODWARD DVR)

Woodward-Clyde Consultants

JAMES R. OBERMEYER
VICE PRESIDENT
WOODWARD-CLYDE CONSULTANTS

Mr. Obermeyer has an M.S. in civil engineering from Columbia University and 14 years experience in civil and geotechnical engineering, primarily in work involving dams. He is the manager of Woodward-Clyde Consultants Civil and Geotechnical Engineering office in Denver. He is a registered professional engineer in Colorado, Wyoming, and Arizona.

His work has included supervision of investigations, analyses, and design of water retention dams, tailing impoundments, and other earth structures. He has been exposed to many facets of dam design including seepage evaluations, embankment stability, abutment erosion, foundation performance, measures to reduce underseepage, hydraulic structure sizing rehabilitation, and reservoir enlargements. His experience includes work on over 75 dams, many of which are located in the Rocky Mountain Region.

Mr. Obermeyer has managed numerous dam projects involving all phases from site selection studies through final design. He is experienced in preparation of plans and specifications, and construction, construction cost estimating, contractor bid evaluations and construction engineering/construction management. He has participated in public hearings and public meetings and served as the resident engineer during the construction of Lake Catamount Dam on the Yampa River in northern Colorado.

Mr. Obermeyer has line management responsibility for team coordination, client relations and quality control of civil and geotechnical projects. His achievements earned him the Woodward-Clyde Consultants' Young Professional Award in 1984.

SEISMIC RISK: COLORADO DAMS

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Eastern Slope Dam Safety Workshop

Sponsored by:
Office of the Colorado State Engineer

Introduction

Very few dam failures have been attributed directly to earthquakes. Seismic activity, however, does pose a serious threat to the safety of dams and needs to be considered during design. Seismic events can result in damage or even failure to dams in several ways. Severe ground shaking can cause settlement or liquefaction of embankment or foundation materials affecting the stability of the dam. Offsets along faults passing through a dam foundation can result in sudden increases in seepage and potential piping failure. Movement along faults located in the dam abutments or reservoir can trigger landslides that could damage the dam or result in a wave of water that would overtop the dam. Seiche waves that could also overtop the dam and cause failure by erosion can be generated by an offset along a fault passing through the reservoir.

The following paper describes the tectonic activity that has shaped the physiography of Colorado, summarizes the seismic history of the state, and describes the procedure for a seismic risk analysis at a dam site and what design measures can be taken to mitigate seismic risk to dams. Finally, a brief analysis of seismic risk in Colorado is made and lays out the general guidelines for earthquake prediction.

Tectonic and Physiographic Setting

The formation of the Rocky Mountains was the result of an intense period of deformation called the Laramide Orogeny beginning in the late Cretaceous (±70 million years) and continuing sporadically through mid-Tertiary (±40 million years) (West, 1986). Another period of post-Laramide deformation beginning in the Miocene epoch (±28 million years) and continuing to the Quaternary period (<1.9 million years) is responsible for the present tectonic and physiographic features of Colorado. The single most important tectonic event in the structural evolution of the state occurred in the late Cenozoic era and is called the Rio Grande Rift.

The Rio Grande Rift, identified in Figure 1, is a fault-bounded structural trough extending 575 miles from southern New Mexico to north-central Colorado. The rift is characterized by a central graben (down-dropped fault block) paralleled by steep mountain fronts on either side resulting from block faulting. The rift system associated with the Rio Grande Rift encompasses most of central Colorado and includes not only the rift itself but associated Neogene block faults. Most of these faults represent reactivation of older faults back to Precambrian time (>600 million years).

Regional Historic Seismic Activity

Figure 1 is a seismotectonic map of Colorado and parts of bordering states (CWDD 1980). Earthquake epicenters, with Richter magnitudes and Modified Mercalli intensity are located on the map along with major faults and other geologic features. The Modified Mercalli scale is based on human observations of earthquakes. Most Colorado earthquakes prior to 1960 have been assigned Modified Mercalli intensities based on newspaper accounts of the events. fter that time a network of seismographs to record the magnitude of ground motion on the Richter scale were in place. Only felt earthquakes or those recorded events with a magnitude of 3.0 or greater are shown on the map. Figure 2 describes the Modified Mercalli scale and shows its relative correlation to the Richter scale.

Historically, nearly all of the seismic activity in Colorado has occurred to the east of a north-south line bisecting the state, between Cheyenne, Wyoming and Raton, New Mexico. The earthquake activity shown on the map characterizes a low level of seismic hazard compared to seismically active areas such as California. The map indicates three relative concentrations of activity. One area is of moderate seismicity located on the west edge of the Uinta Basin in east-central Utah. A second area centers around Dulce, New Mexico near the Colorado border. An intensity VII earthquake capable of modest damage to populated areas occurred in this area in 1966. The third area of moderate activity is located just north of Denver. With the exception of an intensity VII earthquake in 1882, most of these earthquakes occurred between 1962 and 1967 and were associated with a period of subsurface injection of liquid wastes at the Rocky Mountain Arsenal. The nearest area to Colorado where relatively severe earthquakes (intensity VIII) have been recorded is within the southern part of the Rio Grande Rift in the Socorro-Albuquerque region of New Mexico.

Based on the historical record, eastern Colorado can be considered aseismic. The western half of the state can be characterized as a low but non-uniform seismic region where minor earthquakes can be expected, associated with the Rio Grande Rift system.

Seismic Risk Analysis

Current design practice requires that seismic risk be evaluated for any type of dam in almost any location. A seismic risk analysis usually consists of identifying any potentially active faults in the vicinity of the project and the epicentral distance of the nearest point on these faults to the dam. The maximum credible earthquake resulting from movement along that fault should then be determined based on the historic record and probability of occurrence. From this information potential ground motion at the site can be determined. Ground motion is a combination of peak ground acceleration, frequency, and duration of shaking. Ground motion expressed as a design response spectra can then be analyzed and a value for ground acceleration derived for input to the dynamic stability analysis of the dam and foundation.

Design Considerations

The Colorado State Engineer requires that dams be designed with a safety factor greater than 1.0 for extreme loading conditions such as those imparted by an earthquake. Potential damage to dams by earthquakes can be mitigated by several design measures. Earth dams located in areas of high seismic risk should not be constructed on or with potentially liquifiable soils such as low density sands and silts or uniform fine grained cohesionless materials. Soil foundations should be densified as required and fill materials well compacted. Where a potentially active fault passes through the foundation of an earthfill dam, damage caused by an offset could be reduced by placing a sand and gravel zone upstream of the impervious core straddling the fault in order to serve as a crack healer. Stability against damage from shaking can be enhanced by flattening the slopes of the dam or increasing material strengths, either for earthfill or concrete dams, and assuring adequate drainage.

Seismic Risk in Colorado

The entire state of Colorado falls within seismic Zone 1 in the seismic risk map of the United States (Algermisson 1969) (Figure 3), signifying that the maximum intensity earthquake to be expected is VI on the Modified Mercalli scale. The recommended horizontal acceleration to be used for design in this zone is 0.03g to 0.07g.

The Preliminary Map of Young Faults in the United States by the USGS shows several faults in Colorado to have been active since the late Cenozoic era (last 15 million years). Most of these faults are within the Rio Grande Rift or are reactivations of older faults associated with the rift system.

Earthquake Potential in Colorado (Kirkham and Rogers, 1981) recommends that all of Colorado except the northeast corner, be considered seismic risk Zone 2, since several historic events with Modified Mercalli intensities of VII have occurred. The report divides the state into seismotectonic provinces as shown in Figure 1. Maximum credible earthquakes for each province are summarized as follows:

Province	Magnitude
Western Mountain	6.0 - 6.5
Uinta-Elkhead	5.5 - 6.5
Colorado Plateau	5.5 - 6.5
Rio Grande Rift	6.0 - 7.5
Eastern Mountain	6.0 - 6.75
Plains	5.5 - 6.0

The report defines a potentially active fault as Neogene (last 25 million years), although standard engineering practice would consider movement since the late Pleistocene epoch (18 million years) or even Holocene (500,000 years) to be potentially active.

Conclusion

In summary, earthquakes can pose a serious threat to dam safety and must be considered during design. Even though historically Colorado can be considered a region of low seismicity, precautions should be taken at every dam site to perform a seismic risk analysis in order to provide input for the stability analysis of the dam and to assure a design that meets the State Engineer's standards of safety.

References

1. Algermisson, S. T., et al; 1969; Studies in Seismicity and Earthquake Damage Statistics, Appendix B; U. S. Department of Commerce Environmental Science Services Administration.

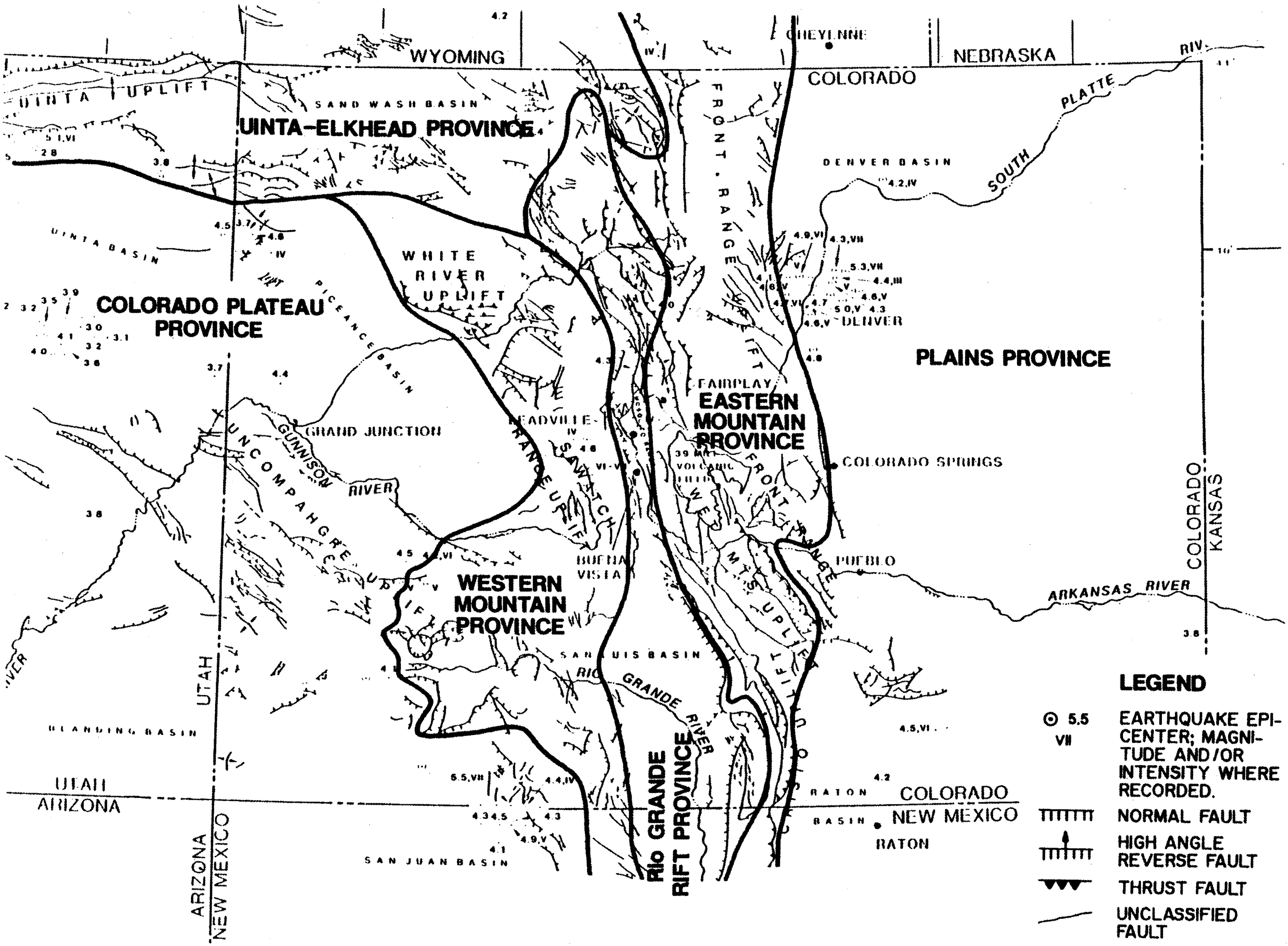
2. Boggs, H. L., et al; 1972; Method for Estimating Design Earthquake Rock Motions; U. S. Department of the Interior, Bureau of Reclamation.

3. Converse-Ward-Davis-Dixon; 1989; Seismic Hazard Evaluation, Spinney Mountain Project, Park County, Colorado; Prepared for R. W. Beck and Associates, and the City of Aurora.

4. ________; Design of Small Dams; 1977; United States Department of the Interior, Bureau of Reclamation.

5. Junge, W. R.; 1981; Colorado Tectonics, Seismicity and Earthquake Hazard: Proceedings of a Symposium Held in Denver, Colorado, June 4-6, 1981.

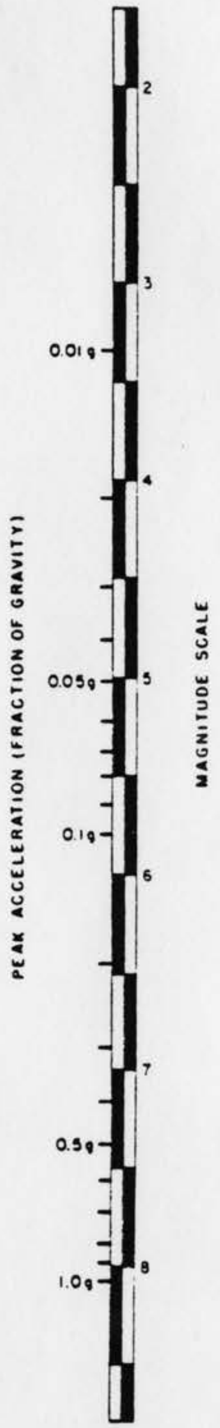
6. West, M. W.; 1986; Seismotectonic Hazard Evaluation, Rock Creek Project near Kremmling, Grande and Routt Counties, Colorado; Prepared for Morrison-Knudsen Engineers, Inc.



SEISMOTECTONIC MAP OF COLORADO

Figure 1

ROSSI-FOREL INTENSITY SCALE (1883)	MODIFIED MERCALLI INTENSITY SCALE [33/]
	I Not felt. Marginal and long-period effects of large earthquakes.
I The shock felt by an experienced observer.	II Felt by persons at rest, on upper floors, or favorably placed.
II Recorded by several seismographs; felt by a small number of persons at rest.	III Felt indoors. Hanging objects swing. Vibration like passing of light trucks. Duration estimated. May not be recognized as an earthquake.
III Felt by several persons at rest; strong enough for the direction or duration to be appreciable.	IV Hanging objects swing. Vibration like passing of heavy trucks. Standing motor cars rock. Windows, dishes, doors rattle. Glasses clink. In upper range of IV wooden walls and frame creak.
IV Felt by persons in motion; disturbance of movable objects, doors, windows; cracking of ceilings.	
V Felt generally by everyone; disturbance of furniture, beds, etc.; ringing of some bells.	V Felt outdoors; direction estimated. Sleepers wakened. Liquids disturbed. Doors swing. Shutters, pictures move. Pendulum clocks stop, start, change rate.
VI General awakening of those asleep; ringing of bells; oscillation of chandeliers; clocks stop; agitation of trees and shrubs; some startled persons leave dwellings.	VI Felt by all. Many frightened and run outdoors. Persons walk unsteadily. Windows, dishes, glassware broken. Books off shelves. Pictures off walls. Furniture moved or overturned. Weak plaster and adobe cracked. Small bells ring.
VII Overthrow of movable objects; fall of plaster; ringing of bells; panic, without great damage to buildings.	VII Difficult to stand. Noticed by drivers of motor cars. Fall of plaster, loose bricks, tiles, etc. Some cracks in masonry. Waves on ponds; water turbid. Small slides, caving of sand or gravel banks. Large bells ring. Concrete irrigation ditches damaged.
VIII Fall of chimneys; cracks in the walls of buildings.	VIII Steering of motor cars affected. Damage to masonry; some partial collapse. Twisting, fall of chimneys, monuments, elevated tanks. Frame houses moved if not bolted down. Branches broken. Changes in springs and wells. Cracks in wet ground and on steep slopes.
IX Partial or total destruction of some buildings.	IX General panic. Weak masonry destroyed, good masonry seriously damaged. Frame structures, if not bolted, shifted off foundations. Frames racked. Serious damage to reservoirs. Underground pipes broken. Ground cracked, sand and mud ejected, earthquake fountains, sand craters.
X Great disaster; ruins; disturbance of the strata, fissures in the ground; rockfalls; landslides, etc.	X Most masonry and frame structures destroyed with their foundations. Serious damage to embankments. Large landslides. Water thrown on banks of canals, rivers, lakes, etc. Rails bent slightly.
	XI Rails bent greatly. Underground pipelines completely out of service.
	XII Damage nearly total. Large rock masses displaced. Lines of sight and level distorted. Objects thrown into the air.



EARTHQUAKE INTENSITY, ACCELERATION AND MAGNITUDE

(Approximate Relationship)

Figure 2

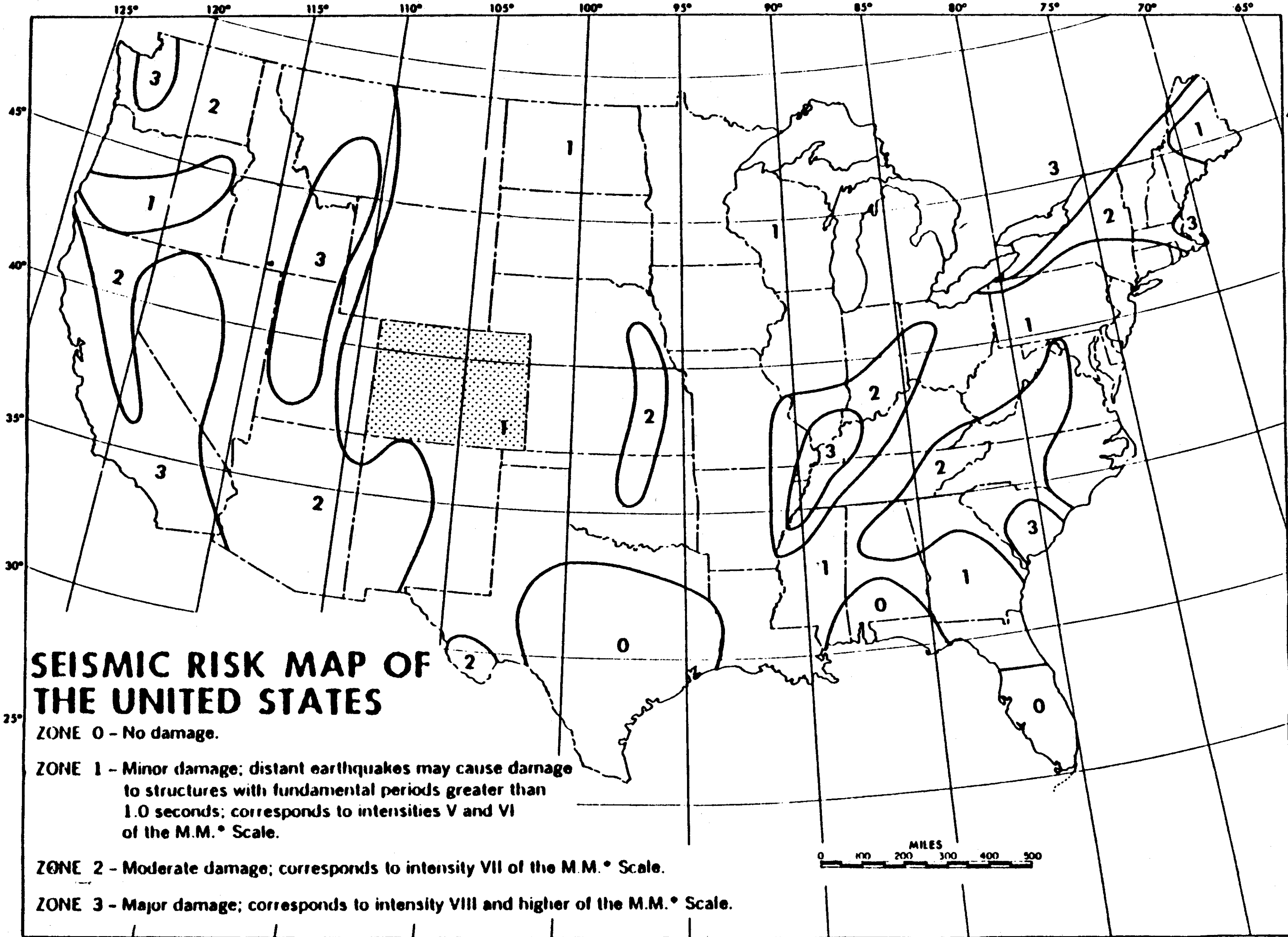
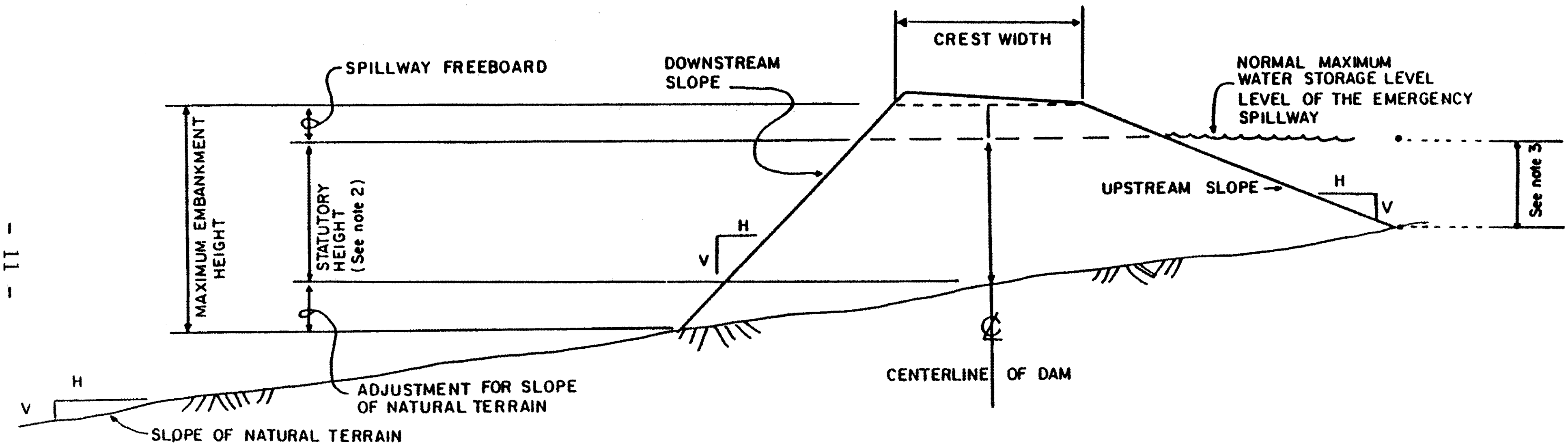

SEISMIC RISK MAP OF
THE UNITED STATES
ZONE 0 - No damage.
ZONE 1 - Minor damage; distant earthquakes may cause damage to structures with fundamental periods greater than 1.0 seconds; corresponds to intensities V and VI of the M.M.* Scale.
ZONE 2 - Moderate damage; corresponds to intensity VII of the M.M.* Scale.
ZONE 3 - Major damage; corresponds to intensity VIII and higher of the M.M.* Scale.
MILES
0 100 200 300 400 500
125° 120° 115° 110° 105° 100° 95° 90° 85° 80° 75° 70° 65°
45° 40° 35° 30° 25°

Figure 3

FIGURE I. DAM CROSS SECTION AT THE MAXIMUM HEIGHT



NOTE: 1. SLOPES ARE EXPRESSED AS A RATIO OF HORIZONTAL DISTANCE (H) TO VERTICAL DISTANCE (V). TYPICAL SLOPES ARE 3:1 ON THE UPSTREAM FACE AND 2:1 ON THE DOWNSTREAM FACE.

2. THIS IS THE HEIGHT OF THE DAM TO THE SPILLWAY AS DESIGNATED IN SECTION 37-87-105, C.R.S. (1973)(1986 Supp.)

3. FOR LIVESTOCK WATER TANKS AND EROSION CONTROL DAMS THE HEIGHT TO THE SPILLWAY MEASUREMENT IS MADE FROM THE UPSTREAM TOE BASED ON ESTABLISHED POLICY.

FIGURE 2 MAP OF COLORADO WATER DIVISION BOUNDARIES AND MAJOR DRAINAGE SYSTEMS