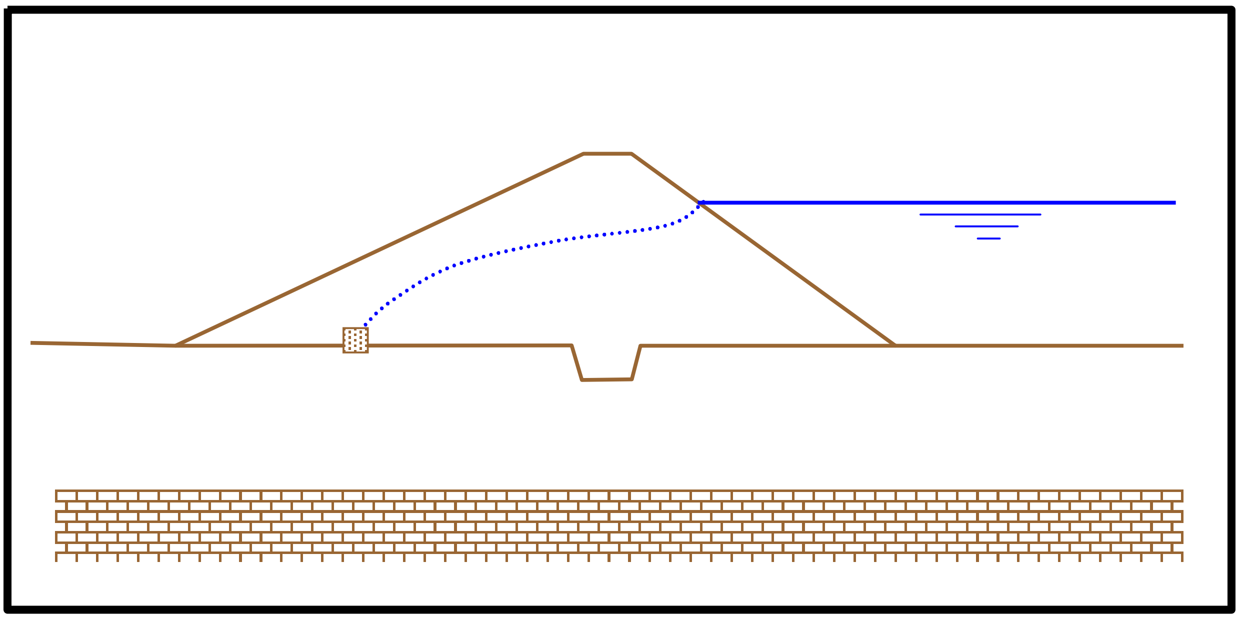
GENERAL GUIDELINES FOR NEW DAMS AND IMPROVEMENTS TO EXISTING DAMS IN INDIANA

2001 Edition



Department of Natural Resources
Division of Water
Indianapolis, Indiana

2010 Appendix A, Appendix B Revisions included

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PREFACE – January 1, 2001

These guidelines are directed to project engineers, technical professionals and owners involved in the design and construction of a proposed dam or the modification of an existing dam that is under the jurisdiction of the Indiana Department of Natural Resources (IDNR). The intent of these guidelines is to provide direction to experienced dam design professionals so that the final product, the dam, is safe and the owner's investment in professional engineering is maximized.

The majority of information given in this document is general and provides many of the dam safety technical principles used throughout the country. The Project Engineer in charge of the design of a dam must be a registered professional engineer and have the training and experience to properly apply these guidelines to the specifics of the site and the needs of the owner. If the owner’s Project Engineer follows these guidelines and an appropriate engineering design package is submitted to Indiana DNR’s Division of Water, the time to obtain approval on the proposed work will be significantly reduced.

These guidelines were modeled after Georgia's Safe Dam Program Engineering Guidelines, 1998 edition. Special thanks are extended to Georgia's Dam Safety personnel and the private engineering community practicing in Georgia for the special opportunity to utilize much of their work in these guidelines.

A committee of 17 professionals from the private engineering community and IDNR contributed significant time to the development of these guidelines. These individuals are listed below:

Siavash Beik	George Crosby	Richard Rampone
Soliman Sherkawi	Jon Stolz	Jack Winters
Ed Board	Scott Ludlow	Chris Ritz
Kenneth Smith	Dave Warder	Dennis Zebell
George Bowman	Christopher Murphy	Jim Sell
Mellissa Stefanovich	Bob Wilkinson	

Special thanks to Debbie Michaels for keying in the text, making revisions to draft copies of this document, and for making copies for distribution, and to Lenny Noens, Herb Bollinger, and Dave Knipe, the north, central, and south engineering basin managers, respectively, for their assistance with the final draft of the hydrology and hydraulics section.

The Federal Emergency Management Agency (FEMA) provided partial funding for the project and the Association of State Dam Safety Officials (ASDSO) encouraged the Division of Water to publish these guidelines. The backing of these two organizations in this project and their long-term support of dam safety efforts in Indiana are appreciated.

Dr. Brian J. Swenty, P.E., Associate Professor and Chair, Mechanical and Civil Engineering Department, University of Evansville, Evansville, Indiana edited the guidelines.

PREFACE – February 1, 2010

Revisions to the guidelines were made in February 2010 to provide clarification in the development of emergency action plans and to properly define hazard class. The definition of hazard classification was developed and defined in regulation and reference to an adapted table is not warranted.
To provide this clarity and new definition,

Appendix A - Table 3 was removed and replaced with the context of the enacted regulation that defines hazard class.

Also, Appendix B – The original "Outline of an Emergency Action Plan" was removed and replaced with a cover sheet that directs the reader to the "Indiana Dam Safety Inspection Manual – Updated 2007" version and Part 4 of that manual. The new Part 4 is entitled "Emergency Preparedness" and represents the recommended guidance for preparation of an Emergency Action Plan (EAP). Templates for an EAP are included in the "Updated 2007 Indiana Dam Safety Inspection Manual".

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Overview

Section 1
OVERVIEW

The general guidelines contained in this manual are useful for the design of small to medium sized dams with the following typical characteristics:

- An earth embankment with appurtenant works constructed to remain stable under a variety of loading conditions for the design life of the structure.
- A properly sized principal spillway that will convey the runoff from normal rainfall events.
- An emergency spillway channel placed an adequate distance from the earth embankment that will operate infrequently and safely pass runoff from the design storm without overtopping the dam.

Guidance on analyses and design issues for innovative, untested, or high-risk dam designs is not covered in these guidelines. The extent of engineering tests, analyses, studies, evaluations, and assessments that are needed to justify an atypical design is beyond the scope of this manual. Further, the time to conduct the additional and extensive engineering analysis and review can be significant when compared to the typical dam described above.

Because each project requires site-specific considerations, these guidelines should not be viewed as a "cookbook" for the design, repair, modification or construction of a dam. The intent of this document is to outline the general technical data, engineering computations, and plans that need to be submitted with the permit application for the proposed work. If these guidelines are followed, the time necessary for the technical review and approval should be reduced. Questions concerning these guidelines should be addressed to the Division of Water at the Indiana Department of Natural Resources, 402 W. Washington Street, Indianapolis, Indiana, 46204.

Dams are complex structures that typically require a multidisciplinary analysis and design approach. Over the years, there have been many incomplete engineering submittals to the Department of Natural Resources (IDNR) that lacked adequate detail in a particular technical area (hydrologic/hydraulic, geotechnical, geological, surveying or structural). The analysis and design of a dam should be supervised by a Project Engineer who is a registered professional engineer. A complete engineering submittal requires adequate technical input and support from hydrologic, hydraulic, geotechnical, geological, structural, and mechanical engineers, as well as licensed land surveyors. It is important for the Project Engineer to consider archaeological and environmental issues in the design or modification of a dam.

An understanding of the roles of the various stakeholders is necessary for the design, construction, and operation of a safe dam.

1.1 Owner's Role

The storage of water is a hazardous activity; it creates increased risk to lives and property situated downstream of the dam. The owner of a dam is responsible for operating and maintaining the dam in a safe manner.

Under Indiana law, IC 14-27-7; "The owner of a dam ... and appurtenant works shall keep the structures and appurtenant works in the state of repair and operating condition required by the following":

- The exercise of prudence.
- Due regard for life or property.
- The application of sound and accepted engineering principles.

A property owner desiring to construct a dam should retain the services of a registered professional engineer experienced in the design and construction of dams and spillways. It is common practice for the owner and the engineer to discuss the owner's needs, the intended purpose of the dam, and the project budget before any design work is performed. During the design process, the owner remains in close contact with the engineer to periodically review the design and the desired project goals.

During construction, the owner works closely with both the engineer and the contractor. Unforeseen site conditions are frequently uncovered that require the owner to approve design changes. The Division of Water should be contacted before field changes are made to the approved plans.

After construction, an owner assumes the role as the primary caretaker of the project. Routine inspection and maintenance allows early detection of many problems that could occur with a dam. The owner should inspect the dam often, keep records of observations and measurements and learn as much as possible about the operation and maintenance of the dam.

Although a dam can be designed and constructed to be a safe structure, lack of routine maintenance and repair, or changing conditions, can eventually cause the dam to become unsafe. If a dam is not in compliance with State law, the owner will be required to improve the dam to bring it into compliance.

The owner may want to confer with an experienced attorney to assess the liabilities of owning a dam.

1.2 Role and Selection of a Project Engineer

The analysis and design of a dam should be supervised by a Project Engineer, who is a registered professional engineer with specialized expertise. These activities require an understanding of hydrology, hydraulics and the behavior of the materials used to construct and support the dam. The Project Engineer will likely need specialized technical input and support from hydraulic, geotechnical, geological, structural, and mechanical engineers as well as licensed land surveyors.

The primary role of a Project Engineer is to provide leadership in the planning, design, and construction of a dam. A Project Engineer is responsible to see that all technical aspects of the dam and site have been completely evaluated. To accomplish this, the Project Engineer works closely with the owner to establish clear objectives and thoroughly evaluate the proposed dam site. A Project Engineer should have the experience necessary to combine the owner's objectives with the site's potential to develop a design for a safe dam. The Project Engineer supervises the preparation of the permit application, plans, specifications and engineering report, but the engineer's involvement does not end with the submittal to IDNR's Division of Water. It is vitally important that the Project Engineer be involved in the construction of the dam to assist the owner is resolving unforeseen problems at the site and ensure that the dam is constructed in accordance with the approved design. Once the dam has been constructed and the reservoir has filled, the Project Engineer should certify that the dam was constructed in accordance with the design plans and submit as-built drawings to the Division of Water.

Because the design of a dam requires a professional engineer who possesses unique abilities, it is preferable to select a Project Engineer based on qualifications rather than fee. While fee-based competition may result in lower initial design costs, lower costs are often associated with inexperienced engineers and frequently limit the engineer's ability to conduct detailed evaluations that are necessary to develop a cost effective and innovative design. Furthermore, a low design cost often results in a significant increase in the cost of construction as well as long term costs associated with operation and maintenance of the dam.

The Project Engineer should be selected on the basis of technical qualifications, experience with similar projects, reputation with other clients, and capability to meet the owner's time schedule. It is usually best to solicit qualification statements from a number of engineers and perhaps interview several of them before making a selection. Once a qualified engineer is selected, the scope of services and fee can be negotiated. If a reasonable fee cannot be agreed upon, negotiations will terminate and discussions can begin with another qualified engineer. It is best, however, if design costs become a factor only after a well qualified professional has been identified.

1.3 Contractor's Role and Selection

The contractor's primary role is to construct the dam and the appurtenant works in accordance with the plans and specifications. It is the contractor's responsibility to notify the engineer of any changes in the site conditions exposed during construction that vary from those shown on the drawings, in the specifications, or in any documents on site investigations. The contractor is responsible to see that the construction is conducted in a safe manner, that all state, federal and local regulations are adhered to during construction, and that the construction site is secure. The contractor is not responsible for the design of the dam or modifications to the design made by the engineer. The contractor is responsible for all construction activities including the quality of workmanship used to construct the dam.

Selection of a qualified contractor is very important. The owner, in consultation with the engineer, should pre-qualify potential bidders. Requests for bids or quotes should be requested from contractors on the pre-qualified list. Items to be considered in the pre-qualification process vary. As a minimum, they should include previous experience in constructing dams comparable in size to the project, a history of satisfactory construction performance, adequate manpower and equipment to complete the project in a reasonable time frame, sufficient financial resources, a history of paying subcontractors, familiarity with local conditions, and a past record of displaying a cooperative attitude. Request and contact references.

The owner should select the best-qualified contractor who responds to the request for bids with a reasonable price for the work. A private owner is not required to select the lowest bidder; a governmental owner may, however, be bound by its enabling statutes to select the lowest bidder. An unusually low bid should be viewed with skepticism. It may be that the contractor has idle resources that are available to do the job, or it may be an indication that the contractor has forgotten something, is inexperienced, or follows a practice of bidding low then negotiating costly change orders during the project.

Bonding of the selected contractor should be included in the contract documents. The contractor should be required to obtain both performance and payment bonds. Payment bond references should be contacted. The contractor should warrant the work against defects for a period of at least one year after completion of the work.

1.4 Project Concept

Prior to constructing a new dam, or modifying an existing dam, certain engineering tasks are typically required to investigate, plan, analyze, and design the project. In many cases environmental, legal, real estate, utility, archaeological, historical, cultural, and other considerations related to a project are investigated and incorporated into project analysis and design. The determination of critical site information during earlier stages of the dam project may have a significant impact upon later stages of the project.

Phased design and construction is a process that should be seriously considered when difficult site conditions are encountered. Dividing a dam project into phases provides all parties with more time to make a reasonable determination of the anticipated scope and costs of the associated investigation, planning, analysis, and design work to be provided in each specific phase. Upon completion and review of each phase, the Project Engineer is better informed and prepared to advise the owner regarding tasks which will be necessary for the next phase. Estimates for construction quantities and costs are continually refined after each phase of the project as more accurate information concerning site conditions and suitable design alternatives becomes available.

Phased design and construction provides intermediate opportunities to discuss information and conditions determined during each project phase with regulatory agencies and stakeholders. Critical input concerning acceptable design methods and procedures can be obtained for application in subsequent phases.

Because the construction of a dam involves a significant financial investment, a primary advantage of phased design and construction is the opportunity it affords an owner to consult with the Project Engineer concerning the overall project and financial direction. Since dam projects are typically complex and very site specific, construction techniques and the scope of work may need to be changed to accommodate site conditions.

Actual project phases may vary and some overlap may occur. Depending on the length of time required to complete each phase, previous data may become obsolete and may need to be updated. Following are typical phases of a dam project through construction:

1.4.1 Reconnaissance Study – This is normally the initial phase of a dam project and involves the following tasks: site inspection of suitable locations for a new dam (or the evaluation of site conditions at an existing dam); discussion of the project goals and objectives with the owner; review of property ownership issues; investigation of available information and previous studies of existing dams; determination of general watershed characteristics, which include geologic conditions, soil conditions, preliminary hydrologic factors, possible access locations, potential downstream effects, and the hazard classification of the dam; evaluation of the potential for future downstream development that might increase the hazard classification during the life of the structure; determination of archaeological or historical limitations; determination of local, state, and federal regulatory jurisdictions; preliminary discussions of the project with regulatory personnel; initial discussions of the project with technical professionals in other disciplines and environmental professionals; and if possible, initial discussion of the project with a suitable contractor(s).

A site reconnaissance can disclose a number of surface features that may provide an indication of the subsurface conditions that exist at the site. These observations involve such items as the extent of alluvial depositions, topography, rock outcroppings, karst features, mining, and vegetative cover. A review of published data, including the geology and general soil conditions of the site, will provide significant additional information. Depending on the complexity of the project, other preliminary evaluation techniques may be considered. This information assists the owner and the design engineer in establishing the best preliminary conceptual design for the project, and provides valuable information concerning those areas where more detailed geotechnical evaluations should be concentrated.

1.4.2 Feasibility Study - Based on the preliminary discussions and the information obtained during the reconnaissance study, a preliminary estimate of anticipated engineering costs, mitigation costs, and possible construction costs is determined. This information provides the owner with an initial opportunity to determine whether the project is financially feasible prior to further expenditures. It is extremely important to remember that preliminary estimates developed during this phase of the project are based on incomplete information and therefore represent only rough estimates of the possible magnitude of the project. These preliminary estimates are not intended to be applied or construed as final project costs.

1.4.3 Preliminary Engineering - During this phase of the project, limited information is obtained through field surveys, geotechnical field testing, and laboratory testing. Studies are undertaken to develop suitable alternatives, including initial estimates of quantities and costs. The Project Engineer assembles a team of qualified technical professionals, based on the project requirements. Suitable topographic maps may be developed from field survey data, a geotechnical report is published, hydrology and hydraulic analysis are conducted, and an environmental reconnaissance is performed. Other studies (water yield, sediment storage, mine tailings storage, etc.) may be performed depending on the scope of the project.

Upon completion of development of suitable alternatives, the Project Engineer presents the results of the preliminary engineering phase, including recommended alternatives to build or improve the dam, to the owner.

1.4.4 Design Phase – After an alternative is selected by the owner, the Project Engineer oversees the final design and preparation of the engineering report, construction plans and technical specifications.

Additional field survey information, geotechnical testing and analysis, environmental reconnaissance, and other technical studies may be required.

Upon completion of the construction plans and specifications, quantity estimates and costs are determined.

1.4.5 Permit Phase - Permit applications for all Local, State, and Federal regulatory agencies having jurisdiction over the project are completed, submitted, and public notice is provided.

1.4.6 Construction Bid Phase – When applicable, construction bid documents are prepared by the Project Engineer's professional team, which provide rules and guidelines for the construction bid process. The construction plans and technical specifications are included as part of the bid documents. Pre-qualification requirements for bidders are established. Requests for bids are distributed to suitable contractors. After receipt of bids, the owner, with the advice of the Project Engineer, selects the best-qualified contractor providing a reasonable price.

1.4.7 Construction Phase - After receiving all permits and approvals, acquiring all necessary property control (property ownership, easements and right-of-ways), and selecting a contractor, construction scheduling and construction activities begin.

Field survey services are used to stake and verify construction locations, alignments, elevations, and grades.

The Project Engineer should be retained to provide construction management services and monitor the construction of the dam. Material testing should be conducted throughout construction to verify that specifications are met. The Project Engineer or a member of the technical team involved in analysis and design should be available for inspection, observation and consultation during all construction activities, especially the excavation of the core trench, the installation of conduits through the dam, the installation of internal drains, and the placement of embankment fill. Because the most dangerous time in the life of a dam is first filling of the reservoir, the Project Engineer should be involved in monitoring this critical phase of the project.

Upon completion of construction activities, the Project Engineer prepares as-built drawings which note any changes or deviations from the approved design/ construction plans and submits the as-builts to the Division of Water.

1.5 IDNR Permit

These Guidelines supplement the Technical Review information in Chapter 5 of the 1996 Indiana Department of Natural Resources Permit Manual. The guidelines provide property owners and their design consultants with general information related to the technical permit requirements for dams in Indiana.

Items related to the completion of the Construction in a Floodway Permit application, environmental issues, and easements are addressed in IDNR's 1996 Permit Manual and should be followed when preparing a permit application.

Prior IDNR approval (permit) should be obtained by anyone desiring to construct or significantly modify (work that is not routine maintenance) a dam before work begins, if the dam meets any one of the following criteria:

- The drainage area above the dam is one (1) square mile or greater.
- The height of the dam, measured from the natural streambed below the crest of the dam to the lowest point on the crest, is equal to or greater than 20 feet.
- The volume of water impounded by the dam at the emergency spillway elevation, is 100 acre-feet or more.

If a permit is required for the proposed project, it will be necessary for the property owner to obtain the services of a registered professional engineer experienced in dam design, construction, repair and maintenance to take responsibility as the Project Engineer.

In order to expedite the permit process, the Project Engineer should meet with the Division of Water staff to discuss details of the project before work commences on the plans, specifications, and engineering report. It is important that all survey, hydrology/hydraulic, geotechnical, structural and mechanical engineering evaluations are complete and accurate prior to submitting an application for a permit. It has been the staff's experience that when incomplete technical information is submitted with the application, the permit process is delayed months and in some cases years.

1.6 Emergency Action Pans

1.6.1 An Emergency Action Plan (EAP) is a formal plan that identifies potential emergency conditions at a dam and outlines the procedures to follow to minimize property damage and loss of life. All high hazard dams should have an EAP (see Appendix B for an outline).

1.6.2 An EAP is needed to preplan the actions taken by the dam owner, State Emergency Management Agency (SEMA) personnel, and local emergency officials during an emergency. This preplanning will help provide for timely notification, warning, and evacuation in the event of an emergency.

1.7 Enforcement Actions

Indiana Code 14-27-7, requires owners to keep their dam in a state of repair and operating condition required by the exercise of prudence, due regard for life or property, and the application of sound and accepted engineering principles. Routine maintenance and compliance with the conditions of the permit are required. A sample owner's inspection checklist is included in Appendix B.

The Division of Water inspects existing dams to determine their condition and continued compliance with state laws, regulations, and policies.

Occasionally, an owner will choose not to maintain the dam or will resist complying with the Indiana Code provisions for constructing and operating a safe dam. Depending on the seriousness of the situation, the Division of Water has several processes for bringing the dam into compliance ranging from certified letters to appropriate litigation. Fines can be issued and the dam can be breached at the owner's expense.

Field Survey

Section 2
FIELD SURVEY

2.1 Introduction

Collection of accurate field survey information is critical to determine existing site conditions, prepare suitable designs, and successfully construct a dam. Accurate field survey information is required for many aspects of a dam project. Listed below are some of the common, acceptable survey principles that are used by professionals practicing in the dam safety field.

2.1.1 Accuracy

The field survey information necessary for designing dams and spillways, developing construction plans, and verifying construction activities is typically required to be accurate, both horizontally and vertically to a minimum of 0.1 foot, except for preliminary and reconnaissance surveys, where horizontal accuracy of one foot may be acceptable. In certain situations, additional accuracy to a minimum of ±0.01 feet may be necessary.

Although less accurate (nearest foot) site information can be used in preliminary stages of the project to determine alternatives and quantity estimates, the Project Engineer should assess the approximate accuracy of this information to make sure reasonable estimates of locations, alignments, grades, and quantities are obtained.

2.1.2 Datum

Temporary benchmarks (TBM) should be established at the dam and tied to an NGVD vertical datum. TBM's can be used to obtain reliable survey data to design, construct and monitor the performance of the dam throughout the project life. Use of established datums connects the dam to other surveys and maps in the area, and enables the Project Engineer to use information from other sources.

Vertical control (elevations) is typically established on the National Geodetic Vertical Datum of 1929 (NGVD'29) or the North American Vertical Datum of 1988 (NAVD'88). Assumed datums may be suitable for minor improvements or repairs.

Horizontal control is important to verify property boundaries and determine the extent of the reservoir at both normal and maximum pool. Control stations for horizontal control should be established on the North American Datum of 1927 (NAD'27) or the North American Datum of 1983 (NAD'83) using Indiana State Plane Coordinates in U.S. Survey Coordinates (feet) or Universal Transverse Mercator (UTM) coordinates (meters). If a sufficient number of permanent survey markers are placed at a site, an assumed datum may be appropriate to monitor the long term performance of a dam.

2.1.3 Property Boundary

The Project Engineer should determine the project boundary and property boundary for the site. This information should be shown on the plans as well as any easements for property that may be inundated by the reservoir during the design flood.

2.2 Topographic Mapping

Development of accurate topographic mapping is desirable in the initial stages of a dam project in order to establish existing locations, alignments, and grades. The topographic information should provide reasonable accuracy for the determination of alternatives and preliminary estimates of quantities. Development of suitable contour information for proposed or existing impoundment areas is especially important in determining stage-storage relationships for the hydrologic/hydraulic analysis.

Due to the extensive areas involved in large dam projects, application of aerial photogrammetry is usually an appropriate and economic alternative for the development of suitable topographic mapping and site layout information. Field surveys are required to establish the coordinate locations and elevations of specified ground control points prior to development of the topographic mapping by aerial photogrammetry. These temporary monuments establish the necessary horizontal and vertical control to develop a topographic map of the site. It is important to note that topographic information developed from photogrammetry is typically accurate to only one half the contour interval of the topographic mapping. For example, elevation information derived from a photogrammetrically compiled map with a contour interval of 2 feet has an accuracy of ±1 foot.

Adjacent property boundaries, utilities, and other important geographical features are determined from appropriate sources and located to the accuracy required on the project site mapping. If appropriate, accurate locations and descriptions of sensitive environmental areas and archaeological resources should be delineated on the project site mapping.

A hydrographic survey of the bed of the lake at an existing dam may be needed to determine storage for a sediment or water supply study.

2.3 Field Survey for Geotechnical Testing

Field survey information is typically required in conjunction with geotechnical testing to precisely locate test borings and provide accurate cross-sections of existing dams at specified locations for stability analysis.

2.4 Field Survey for Hydrology and Hydraulics Analysis

Field survey information required for the hydrology and hydraulics analysis includes the determination of spillway control elevations and structural details for spillways at both new and existing dams. These details include the type of structure, location, size, alignment, inlet and outlet elevations, length, outlet type, and other requested structure characteristics to determine losses in both open channels and closed conduits. Accurate determination of an existing lake pool elevation is important to help establish the stage-storage relationship for reservoir routing calculations.

Profiles and cross-sections of natural and man-made channels into which existing or proposed spillway structures will drain are typically required to determine potential backwater effects at spillway structures, the need for channel armor protection, and the design of energy dissipation devices.

For existing dams that have lake drawdown structures, inlet and outlet invert elevations, the length, diameter, and material of the pipe and the size and description of all valves, should be determined.

Finally, for both existing and proposed dams, information about downstream structures (i.e. culverts, bridges, dams, levees, placed fill, etc.) that may restrict flows and result in backwater effects at spillway structures should be determined. It is important that the datum used at any other structure be the same datum that is used at the dam.

2.5 Field Survey for Preparation of Final Designs and Construction Plans

Prior to the preparation of final designs and construction plans for a new dam or improvements to an existing dam, extensive field survey information is required to accurately define the physical characteristics of the project site. Field survey cross-sections should be obtained at intervals along the centerline of a proposed or existing dam and at appropriate intervals along the length of emergency spillways.

2.6 Construction Survey

Prior to the actual construction of the dam, a construction survey is necessary to stake actual locations, alignments, and grades of structures shown on the construction plan. During construction, additional field surveys may be required to verify information on the construction plans and to determine accurate construction quantities. It is recommended that the bottom of the core trench, internal drains, pipes through the embankment, and buried structures be surveyed before backfilling occurs.

2.7 Post Construction Survey

An as-built survey is typically performed after the completion of all construction activity to determine if the structure was built according to the plans. In some instances, the as-built survey data is used to perform hydraulic, hydrologic and geotechnical computations to verify that the dam meets minimum safety requirements.

On some dams, typically only large high-hazard dams, annual or other periodic surveys are conducted to monitor movement of the embankment and appurtenant structures.

Geotechnical and Geological Considerations

Section 3

GEOTECHNICAL AND GEOLOGICAL CONSIDERATIONS

3.1 Introduction

The identification of the site characteristics, engineering properties of the materials used to construct the dam, and geologic conditions beneath the embankment are essential to the design of a safe dam.

The geotechnical and geologic guidelines that follow are predicated on a "typical" project, generally involving a small or medium sized dam at a site with few geological challenges. It should be understood that each and every project is unique, and the geotechnical requirements may be modified accordingly. The type and quantity of field and laboratory tests conducted and the types and numbers of analyses performed will be influenced by the hazard classification and project function. A limited geotechnical investigation may be allowed on small, low-hazard dams while a comprehensive investigation is recommended for large, high-hazard dams. Unauthorized dams will require a geotechnical investigation and the same geotechnical computations as a new dam.

Structures in heterogeneous geologic settings, such as solutioned limestone or lakebed sediments may require extensive geotechnical studies. Subsurface conditions can change dramatically across a valley. Larger dams and dams with very long crest lengths may necessitate additional geotechnical investigations to properly assess the subsurface conditions.

Geotechnical evaluations for the rehabilitation of existing dams should consider the seriousness of the deficiencies. For major rehabilitation projects such as repairing breached dams, increasing the height of a dam, permanently raising the normal pool elevation of the reservoir, repairing embankment slides, modifying excessively steep slopes, and constructing control structures for extensive uncontrolled seepage and piping, the geotechnical evaluations should essentially be the same as that utilized for a new dam. The evaluation should be modified, as necessary, to target the major deficiency(s) identified. Limited geotechnical evaluations are typically acceptable for minor rehabilitation projects such as minor seepage, unsuitable vegetation and minor slope reconfiguration.

3.2 Literature and Initial Review

The development of the subsurface exploratory program should begin with a literature review of existing geologic and geotechnical maps, reports, and other records that might provide technical background information on special conditions at the site and the surrounding area**.** The project details will dictate the extent of the literature search that would be beneficial in the development of the subsurface exploration program. Listed below are some sources of information that may prove helpful.

3.2.1 Geologic Maps and other geologic information

State geologic mapping will provide an indication of the geologic setting of the site. Local, detailed geologic mapping and pertinent information may be available in or near the project area. The Indiana Geological Survey (IGS) located in Bloomington has a wealth of information on the geology of the state and trained professionals that can assist in the interpretation of this information. General information about the IGS can be obtained from the web site "http://adamite.igs. indiana.edu/index.htm".

3.2.2 Soil Surveys

All Indiana counties have existing soil surveys that contain information on the surficial soils. These are particularly useful in the preliminary phase of planning a subsurface exploration program. Almost all counties have a Natural Resources Conservation Service office staffed with technical professionals that can address general soil conditions of the site.

3.2.3 USGS Topographic Quadrangle Maps

Topographic maps provide a general characterization of the surface features of the area under investigation and the drainage patterns which may influence site selection. U.S.G.S. 7 ½ minute topographic maps are available for the entire state. More detailed topographic mapping may be available for certain local areas.

3.2.4 Other Sources of information

- Aerial Photographs
- Well Records
- Technical publications pertaining to the area
- Technical records or inspection reports on existing dams near the site
- Special maps (abandon coalmines, underground caves, etc.)

3.3 Site Reconnaissance

A thorough reconnaissance of the entire site and adjacent areas by the Project Engineer and the geotechnical engineer or engineering geologist is considered to be essential for both new dams and major modifications to existing dams. Typically, a reconnaissance is performed prior to implementing the exploration program to determine the best methods to employ. Additional site reconnaissance may be conducted during or after the field program to help interpret the data being obtained. Vegetative cover, rock outcroppings, and small topographic features (that may not be discerned from the literature review alone) provide useful input.

The primary emphasis of the site reconnaissance is the area within the embankment footprint and areas immediately upstream and downstream. These would include the creek bottom, flood plain, abutments, and any potential open channel spillway alignments within the abutments or areas removed from the dam site. In certain instances, the reconnaissance may include the entire reservoir footprint. It is very important for the reconnaissance team to include the land owner in the site reconnaissance to help identify potential borrow sources and locations of unusual geologic conditions such as rock outcroppings, caves, and springs. A downstream inspection is recommended to better identify the hazard classification.

3.4 Geologic Mapping

Site-specific geologic mapping may be warranted in some instances. This would be particularly applicable to large dams, and those located in unique geologic settings. The applicability of such a method (prior to the subsurface exploration program) is directly related to the amount of rock outcropping that may be identified during the site reconnaissance. In the absence of outcroppings, geologic mapping may be of limited use. Where shallow rock exists, that is not otherwise exposed, test trenches may be appropriate to expose these materials for direct observation.

3.5 Subsurface Exploratory Program

The objective of a successful subsurface exploration program is to strategically obtain samples and pertinent information for an engineering evaluation of all the materials that will affect the performance of the dam and appurtenant works. The Project Engineer should balance the use of in-situ exploratory procedures with the option of obtaining both disturbed and undisturbed samples for laboratory testing. On large dam projects, strength and permeability tests are usually performed on undisturbed foundation samples and remolded samples of borrow material. For small, low hazard dams, laboratory identification tests of bagged samples can be used to obtain assumed shear strength and permeability parameters. The use of conservative shear strength parameters may result in an over-designed structure, thus the Project Engineer must balance the cost of exploration with the cost of over-designing and over-building the dam. Using assumed shear strength parameters may be a reasonable approach for small, low hazard dams, but should not be used for large dams. The use of a haphazard approach to subsurface exploration wastes money and can lead to the design and construction of a potentially unsafe dam where failure may result.

3.5.1 Test Borings

Test borings are typically placed within the footprint of the dam and appurtenant structures. Boring locations on existing dams should target the specific deficiencies identified while considering accessibility to the site. For existing dams with minor deficiencies where sufficient documentation concerning the design, construction, and performance of the dam is available, the need for borings may be minimal.

3.5.1.1 Centerline of the Dam - The number of test borings along the centerline of the dam should be based on the needs of the design. Past experience indicates that three borings along the centerline of small dams with a short crest length is adequate.

3.5.1.2 Embankment Toe - Borings at the upstream and downstream toe should be considered for most dams to delineate the soil stratigraphy in the valley.

3.5.1.3 Conduit and Internal Drain Locations - Additional borings may need to be placed beneath proposed conduit and drain locations to identify subsurface conditions within these specific areas. These borings can provide information to evaluate highly compressible soil layers, weak foundation soils, permeable anisotropic soils, and high ground water conditions.

3.5.1.4 Open Channel Spillways - Open channel spillways in the abutments are typically evaluated with borings, if significant depth of excavation is anticipated. These borings should at least penetrate the depths of excavation and identify the properties of the materials at the base of the channel.

3.5.1.5 Depths and Samples - Boring depths within the embankment footprint area will generally mirror the height of the embankment above each individual boring, with a minimum depth of 15 feet typical. Disturbed samples obtained by Standard Penetration Testing, or other suitable methods, are normally made on 2.5-foot intervals unless there is evidence that the material is relatively homogeneous in which case 5.0-foot intervals may be appropriate.

3.5.2 Test Pits

Test pits excavated with a backhoe can provide useful information in certain portions of the site. Several excavations often allow a more thorough assessment of the upper stratigraphy, and can provide indications of potential difficulties that may be encountered during construction. In situations where the dam is a small, low hazard structure and sound, tight rock is near the surface, test pits that may significantly reduce the quantity of borings. Otherwise the following should be considered:

3.5.2.1 Flood plain - Alluvial deposition is typically complex. Soil test borings alone often do not clearly represent the conditions encountered within flood plain areas. Test pits can provide a better indication of subsurface variability, depths of organic material, past seismic activity, and difficulties that may be encountered relative to groundwater inflow.

3.5.2.2 Shallow Rock - Test pits may be used to supplement the evaluation of general areas where shallow rock is encountered. This helps discern if the refusal materials are fairly continuous rock and whether the rock surface is uniform. This may be particularly useful at sites with karst geology.

3.5.2.3 Open Channel Spillways - Test pits may be an inexpensive means of evaluating areas where the depths of excavation anticipated for channel spillways are minimal.

3.5.3 Rock Coring

Some rock coring is recommended within the footprint of the dam if refusal is encountered at depths less than about half the originally planned boring depth, with appropriate consideration of the geology of the site.

3.5.3.1 Depths - The amount of rock core to be obtained in each hole depends on a number of factors including the size of the dam, geologic setting, and rock quality. Typically, a minimum of 10 feet of rock should be cored at each location.

3.5.3.2 Packer Tests - Packer permeability tests may be performed in conjunction with the rock coring where there is an indication the rock mass is jointed, solutioned, or has significant discontinuities. The Packer Test will assist the geotechnical engineer in determining the hydraulic conductivity of the rock mass (see section 3.7).

3.5.4 Preliminary Instrumentation for Piezometric Levels

The subsurface exploratory program may include the installation of observation wells or piezometers to establish the groundwater conditions within the footprint of a proposed dam or assess seepage-related deficiencies in an existing dam.

Strategically placed piezometers can provide valuable information on conditions in existing dams. For new dams, the installation of piezometers allows the geotechnical engineer to monitor pore pressures during first filling of the reservoir and throughout the life of the structure. This data can be used for analyses and for long term monitoring of dams. See Section 3.10 and Geotechnical Addendum/Instrumentation in Appendix C for further discussion.

3.5.5 Test Samples

3.5.5.1 Disturbed Samples - Split-spoon samples from borings and samples from test pits should be obtained for classification and correlation.

3.5.5.2 Undisturbed samples - A sufficient number of relatively undisturbed samples should be obtained to evaluate foundation materials, especially at large dams. A sufficient number of samples are needed to accurately characterize the differing types of materials present in the valley and abutments. Strength, compression, and permeability tests on undisturbed samples produce data that is helpful in evaluating the stability of the dam and determining the expected behavior of the materials left in place to support the dam.

3.5.5.3 Bulk Samples - Disturbed bulk samples from test pits or auger cuttings are typically collected, particularly for explorations made in open channel spillway areas and potential borrow areas.

3.5.6 Other Exploration Techniques

Several other exploration techniques may be considered in special situations to address specific areas of concern. Examples include pressuremeter testing or cone penetrometer soundings, particularly in soft foundation materials that may be left in place to support the dam. Geophysical exploration techniques may also be appropriate in some instances.

3.6 Borrow Study

The ultimate purpose of a borrow study is to identify sufficient quantities of acceptable borrow materials that can be used in the construction of the dam. This can be accomplished by estimating the quantity of material needed in the dam and conducting adequate explorations and laboratory analyses to determine the soil profiles in the borrow areas.

3.6.1 Locations

It is important to locate the borrow areas far enough away from the dam so that any excavation below the top of dam elevation does not jeopardize the integrity or the performance of the structure. There are many site and project specifics that will dictate this distance. For small to medium sized dams situated on a geologically “good” site, the location of any borrow area that will be below the dam crest elevation should be kept 200 feet or more from the dam.

3.6.1.1 Open Channel Spillways - For projects involving the excavation of open channel spillways in the abutment areas, it is recommended that these materials be evaluated for use in the construction of the dam. See Sections 3.5.1.4 and 3.5.2.3.

3.6.1.2 Reservoir Area - Any portion of the reservoir area that will be excavated for borrow material should be investigated. Under no circumstances should bedrock be uncovered and left exposed in a borrow area that is within the reservoir boundary.

3.6.2 Exploratory Techniques

The exploration of potential borrow sites should be sufficient to characterize the usable soil deposits(s) both from a geological and engineering perspective. The study should demonstrate homogeneity relative to the deposit(s) under consideration. Exploratory holes are typically placed on approximately 500-foot centers on a rough grid system at all practical locations.

3.6.2.1 Test Pits - Test pits are the preferred exploration technique for the evaluation of borrow sources where the potential depths of excavation are limited, or where the occurrence of suitable material is near the surface. Soil stratigraphy can be determined in more detail, and the variability and inclusion of unsuitable materials may be more readily observed with test pits. Discreet sampling of specific soil layers and combined sampling of two soils in the vertical profile can easily be done using this technique.

3.6.2.2 Borings - Auger borings are typically required where greater excavation depths are planned.

3.6.3 Sampling

Small grab samples of foundation, abutment, and borrow materials are useful for general classification purposes. Sealed samples of this type can be used to determine in-situ moisture contents. Bulk samples are required on all materials that may be used as embankment fill. Sufficient quantities of bulk material are obtained based on the types of laboratory tests to be performed.

3.7 In-Situ/Field Testing

In-situ testing, or field testing, may be considered in the evaluation of foundation conditions for new dams and in the evaluation of conditions within and beneath existing dams. Typical conditions that may warrant in-situ testing include soft compressible foundation materials that cannot be sampled routinely for laboratory testing, evaluation of seepage through foundations and existing embankments, evaluation of the continuity and integrity of foundation rock, and the determination of excavation quantities and methods.

The utilization of field test methods will depend on the size and length of the dam, the type and extent of foundation materials encountered, and the economic feasibility of a particular method over another. In-situ methods may be used to supplement more common exploration techniques such as soil test borings. Some geologic settings and embankment conditions may necessitate the use of one or more of these methods (see Appendix C - Geotechnical Addendum - Insitu/Field Testing).

3.8 Laboratory Testing

The laboratory testing program typically consists of soil classification and may also include a determination of shear strength parameters, permeability, and compressibility properties of soils. Appropriate in-situ tests may be considered for foundation materials. Laboratory testing of remodeled samples of potential embankment materials is typically needed to determine the strength of the material. Depending on the size and hazard classification of the dam, a relatively extensive testing program may be required to characterize all of the material types in the foundation and the embankment**.** It may be necessary to perform duplicate tests on significant soil material types to verify a typical value of the material being tested.

3.8.1 Characterization Testing

This type of testing is typically performed to provide an indication of the engineering characteristics of the materials that will be used to construct the dam. These tests also provide identification of the different types of materials involved so that more extensive testing can be targeted to specific material groups.

3.8.1.1 Classification Tests - General classification tests, suitable for classifying soils by the United Soil Classification System (USCS), include gradation tests (sieve and hydrometer, as required) and Atterberg Limits tests.

3.8.1.2 Compaction Tests - Proctor compaction tests, and associated natural moisture content tests are needed to establish the basis for quality control during construction and to provide samples for strength testing. Standard Proctor compaction tests are typically utilized.

3.8.2 Strength Testing

Strength testing will normally be required to determine the shear strength parameters for the stability evaluation of both new and existing dams. Tests are typically performed on relatively undisturbed samples of foundation materials and existing embankment materials. Remolded samples of potential borrow materials are compacted to the minimum value allowed in the technical specifications and tested to determine the shear strength of the material that will be used to construct the new embankment. The state encourages engineers to perform triaxial tests on foundation and embankment soils for significant and high hazard dams. For small, low hazard dams, estimated shear strength parameters may be selected from published data in the Bureau of Reclamation's *Design of Small Dams* for the embankment and foundation material. Estimates should be based on the results of soil classification tests (Atterberg Limits, Sieve Analysis, and Hydrometer Analysis).

3.8.2.1 Triaxial Shear - Laboratory strength parameters are typically evaluated using consolidated undrained (CU) triaxial shear strength tests with pore pressure measurements. The CU test provides both total and effective strength parameters.

3.8.2.2 Direct Shear - Direct shear tests may be considered in certain instances. However, these tests are less accurate than triaxial tests and are becoming less common in the determination of strength parameters for earth dam stability computations.

3.8.2.3 Unconfined Compression - Unconfined compression tests can provide a general indication of undrained shear strength of clayey soils.

3.8.3 Consolidation Testing

Where settlement is an issue, an adequate number of consolidation tests on undisturbed foundation samples are needed to establish the settlement characteristics. Consolidation tests may also be performed on samples from proposed borrow areas that are remolded to provide reliable settlement and deformation data on each soil type proposed for the embankment.

3.8.4 Permeability Testing

Depending on the dam size and the embankment and foundation characteristics, permeability tests may need to be performed on undisturbed samples from the foundation of new and existing dams. When seepage is a concern in an existing dam, permeability tests of undisturbed embankment materials may be necessary. For new dams, remolded samples of proposed borrow materials may require permeability testing. These tests are typically performed on saturated samples to establish hydraulic conductivity characteristics of the various soil types involved. Both falling and constant head tests can be performed.

3.9 Geotechnical Analyses

Appropriate geotechnical analyses are performed to determine the geometry of the dam, the size and location of internal drains, the location of conduits within the embankment, and the location of appurtenant structures. The accuracy of these analyses depends on the validity of the parameters and assumptions developed in the preceding sections. Additional field and laboratory work may be necessary to improve the accuracy of the geotechnical models that are used by the engineer. Critical sections of the embankment should be evaluated for all expected loading conditions that could occur during the life of the dam. The intent of the geotechnical analyses is to design a safe and satisfactorily functioning structure at the lowest feasible cost.

The geotechnical design typically includes the following:

1. Provisions for monitoring the performance of the dam and maintaining the structure to assure satisfactory performance throughout its design life.

2. Evaluation of the stability of the structure during construction, at the end of construction, and during steady seepage conditions.

3. Evaluation of the stability of the dam and appurtenant structures during and after seismic events.

4. Evaluation of the stability of the dam and appurtenant structures during a rapid drawdown of the reservoir.

5. Ability of the embankment, internal drains, and appurtenant structures to experience minor consolidation settlements without adverse affects.

6. Monitoring, collection, and control of seepage through the embankment, foundation and abutments.

3.9.1 Stability Analysis

The purpose of a slope stability analysis is to determine a factor of safety for the embankment which is defined as the ratio of resisting forces (gravity forces and soil shear strength) to driving forces (gravity forces and shear stresses) along the critical potential failure surface.

For existing dams, the primary purpose of the stability analysis is to determine if the embankment is stable under various loading conditions. A stability analysis can be used to evaluate a slope failure that has occurred, design modifications to improve the stability of the embankment, or evaluate proposed changes to the height of the dam or the reservoir elevation. Loading conditions are typically limited to steady seepage-full pool, steady seepage-maximum pool, rapid drawdown, and seismic events.

For new dams, the purpose of the stability analysis is to design an embankment that will meet minimum factors of safety for a variety of loading conditions. These include loading during construction and at the end-of-construction. During the placement of fill, the construction schedule and any external loading should be considered in the analysis of the embankment. The end of construction condition is typically only of concern when rapid fill placement occurs on very soft foundations and undrained conditions occur. The steady state stability of the downstream slope should be analyzed under two loading conditions: the reservoir at the normal pool elevation after development of the steady state phreatic surface and the reservoir at the maximum pool elevation. Where drawdown facilities exist, the stability of the upstream slope is analyzed under rapid drawdown conditions. In limited instances, rapid drawdown due to submergence of the downstream toe may be a consideration. In high seismic zones, a seismic stability analysis should be performed for the downstream slope using an appropriate factor of gravity (i.e. 0.15g) for the design acceleration.

For the end-of-construction condition, the shear strengths of the foundation and dam fill are typically evaluated using total stress conditions (undrained shear strength) where the fill is placed rapidly upon the foundation materials and excess pore pressures have not dissipated. Where the foundation materials are very fine grained and the build-up of excess pore pressure could be detrimental, piezometers should be installed in the foundation to monitor the pore pressure during construction.

For steady state conditions, the stability analysis should be performed under the assumption that the phreatic surface has been developed. The phreatic surface will begin at the "normal" pool elevation of the upstream face and extend to either the internal drainage system or the downstream slope of the dam, as determined through use of constructed flow nets or finite element seepage analysis. Drained shear strength parameters should be used to evaluate the dam under steady seepage conditions.

Drawdown pipes are encouraged for all dams, especially high hazard dams. Valves should be placed at the upstream end of the pipe to prevent the pipe from being pressurized when it is not in use. Rapid drawdown could occur if the reservoir is lowered at a rapid enough rate to prevent dissipation of the pore pressures at the upstream face of the dam. For dams built of cohesive soils, excess pore pressures may result if the drawdown exceeds 1 foot per week. This could cause an upstream slope failure that could damage the embankment and ultimately lead to the breaching of the dam. A rapid drawdown stability analysis is performed using drained shear strength parameters for the embankment. The reservoir is assumed to be at the invert elevation of the drawdown pipe and embankment pore pressures are computed with the reservoir at normal pool.

After completion of the static analyses, each of the loading considerations should be analyzed considering the appropriate seismic ground acceleration forces. Typically a pseudo-static analysis of only the downstream slope at steady state seepage conditions is performed.

Stability analysis for earth embankments should consider both slip circle methods such as Bishop, Spencer, Morganstern-Price, or Janbu's, and when appropriate, sliding wedge analyses. There are numerous computer programs which are accepted by IDNR’s Division of Water for the performance of stability analyses. The geotechnical engineer is responsible for verifying that the computer stability analyses are correct.

3.9.2 Seepage Analysis

Water will seep through all earth embankments over a period of time. Therefore, it is imperative that this seepage be recognized, monitored, and controlled. A seepage analysis may be necessary to determine pore pressures within the embankment, assess the effectiveness of seepage control options, provide quantitative data for the design of seepage control structures, and predict seepage behavior of the embankment and foundation. The analyses can assist in locating piezometers for use in monitoring seepage through the embankment and foundation.

After the phreatic surface has developed, the permeability of the embankment and foundation materials will determine the seepage flow rate. If the rate is excessive, seepage reduction and seepage collection techniques may be needed. The quantity of seepage flow, the hydraulic gradient through the dam, and the long-term effects of the exit gradient on embankment performance are of particular interest to the geotechnical engineer. Seepage reduction techniques such as cut-off keyways, slurry walls, clay core zones, and grout curtains should be considered. The seepage analysis can be used to select the most effective type of internal drainage system for the dam and foundation.

Permeability data is typically obtained from appropriate laboratory and field tests. The seepage analysis should be performed on the maximum dam cross-section upon completion of the field and laboratory testing. Either a graphical flow net analysis or a more sophisticated numerical finite element model can be used.

Analytical models will aid the geotechnical engineer in determining critical seepage areas within the dam and appurtenant structures. These include areas of excess pore pressure and high gradients. The analysis should consider the proposed drainage system to allow accurate modeling of the phreatic surface, and exit gradients at the toe of the dam. Such analysis will aid in determining if special seepage devices, such as relief wells, will be required in the final design.

It is imperative that the geotechnical engineer be aware of the implications of the seepage analysis. It is always advisable to perform an independent check of any computer calculations to verify that the results are reasonable and within tolerable limits for the structure.

3.9.3 Settlement Analysis

Both the new embankment and the foundation soils will consolidate beneath the weight of the embankment materials. The amount and rate of settlement will depend on the consolidation characteristics of the underlying soils and the rate of pore pressure dissipation. Settlement of the embankment can result in loss of freeboard, depressions on the dam crest, differential settlement along conduits which penetrate the dam, and in extreme cases, transverse cracks that can lead to failure of the dam. Excessive settlement can cause misalignment of conduits, separation of joints, and possible conduit failure which results in leaking and possible soil piping (internal erosion of embankment soils).

It may be necessary to analyze settlement to determine foundation treatment and camber, for the embankment and appurtenant structures. Laboratory consolidation tests should be performed to determine the consolidation and drainage characteristics of the embankment and foundation materials. The geotechnical engineer should consider performing a one-dimensional settlement analysis, which considers the variable loadings across the dam footprint to determine areas of critical movement. If differential settlement and cracking of the embankment is possible, the geotechnical engineer should consider chimney drains, settlement accommodation along conduits, and joint extensibility for any jointed conduits. The effects of the calculated vertical movements on both the embankment and the appurtenant structures should be carefully considered in the design.

3.10 Instrumentation

Various instrumentation devices are typically required in the construction of large, high-hazard dams, and may be necessary on existing dam rehabilitation projects. Instrumentation can be installed to monitor the performance of the dam during construction, during initial reservoir filling, and during the life of the structure. Foundation and embankment performance may be monitored with piezometers, settlement devices, inclinometers, and seepage measuring devices. Other less common instrumentation may be considered for unusual conditions. Any instrumentation selected should target specific items to be evaluated, establish critical thresholds that suggest the need for a specific action, and establish the details of the monitoring program (see Appendix C - Geotechnical Addendum Instrumentation).

3.11 Geotechnical Report

Once the field exploration, laboratory testing program, and geotechnical analyses have been completed, a final report outlining these items as well as the geotechnical aspects of construction should be prepared. A wide range of report formats is possible. However, the following items should generally be included.

3.11.1 Introduction

A general statement of the purpose of the geotechnical study.

3.11.2 Project Information

A detailed description of the project being evaluated should be documented as part of the report. This is particularly useful if the design changes significantly from the time the geotechnical study was performed to the completion of the design documents.

3.11.3 Exploration Procedures

This section should include a description of the field and laboratory testing procedures utilized in the study.

3.11.4 Site Description

A brief description of the surface features of the project area is helpful. This includes the project location, surface topography, vegetative cover, and identifiable surface features. The site description essentially summarizes the site reconnaissance observations.

3.11.5 Subsurface Conditions

A brief summary of the subsurface conditions identified by the field exploration program should be included. This summary generally identifies the major types of materials encountered and provides correlations between borings based on the data obtained. This section of the report identifies information gleaned from the desktop study and any geologic field mapping of the site. The intent of this section is to relate the identified subsurface conditions to the known geologic conditions at in the site, and set the stage for addressing any special or unusual conditions in the conclusions and recommendations section(s) of the report.

3.11.6 Findings

This section summarizes the results of the stability, seepage, and settlement evaluations. The results should be placed in this section or intertwined with other sections of the report. By summarizing the evaluations that were performed, the basis for the design, construction conclusions, and recommendations are established.

3.11.7 Conclusions and Recommendations

This section of the report is the most critical and should identify all of the geotechnically related design and construction items that will impact, and be incorporated into, the design contract documents. Design and construction related conclusions and recommendations might be separated or combined. Any areas of uncertainty, such as items that can only be resolved by further evaluation during the actual construction process, should be clearly identified in this section. The following items should be addressed in this significant portion of the geotechnical report.

3.11.7.1 General Assessment - A brief summary of the more significant conclusions and recommendations is included, identifying unusual or critical items that should be addressed in the design and construction.

3.11.7.2 Site and Subgrade Preparation - Recommendations concerning clearing, stripping, and grubbing of the embankment footprint area, spillway locations, and potential borrow areas should be included. All disturbance and excavation limits should be based on safety considerations. Typically, the area beyond the toe of the dam is cleared to minimize root invasion.

3.11.7.3 Foundation Preparation - Recommendations concerning undercutting and replacement of unsuitable materials should be included in this section.

Special foundation preparation techniques are included to deal with partial undercutting of alluvial soils and the preparation of exposed rock foundations.

3.11.7.4 Groundwater and Dewatering - Dewatering requirements to construct the project should be identified. Specific areas that will likely require dewatering, and the extent to which groundwater lowering is needed, should be addressed. General information on the anticipated types of dewatering systems that would be appropriate should be presented.

3.11.7.5 Surface Water Diversion - A general discussion of the need to route surface flows from the drainage basin around and through the construction work area should be identified.

3.11.7.6 Seepage Considerations - The seepage evaluations should include estimates of potential seepage quantities, as well as any seepage reduction and seepage collection techniques needed. Seepage reduction techniques such as cutoff/keyways, slurry walls, clay core zones and grout curtains should be identified. Internal drainage system recommendations should be made for any foundation and embankment drains that are needed. Details concerning gradations of drainage aggregates, filter requirements, the need for special items such as relief wells, and locations and minimum dimensions for drainage components should be addressed.

3.11.7.7 Embankment Geometry - The maximum recommended slope inclination should be specified based on the results of the stability evaluation. The need for toe berms, wave berms, and minimum crest widths should be discussed as well as drainage considerations for the surface of the embankment. Any requirements for zoning within the embankment should be included, specifically addressing material properties that are considered appropriate for each zone within the dam.

3.11.7.8 Earthwork Recommendations - This section of the report should include the material types and quantities identified in potential borrow areas. It should specify minimum compaction requirements and moisture control for all fill material placed during construction. Borrow site management should be addressed. Details concerning the placement procedures for the earthwork operations to assure adequate bonding between lifts, control of overly wet, dry or frozen materials, cross slopes, and management of the fill pad should be provided. Minimum testing recommendations for the earthwork should be included.

3.11.7.9 Settlement - Estimates of settlement, particularly at critical structure locations, should be provided if compressible foundation conditions exist. In conjunction with the settlement assessment, anticipated settlement along conduits and the associated joint extensibility for any jointed conduits should be described. The potential for excessive differential settlement should be discussed as well as any special foundation preparation techniques or design requirements, such as internal drainage systems and chimney drains. Typically, the settlement estimated at the base of the dam, as well as the settlement within the fill material should be provided. The need to compensate for any potential settlement, including cambering of the crest, special construction sequencing and surcharging requirements should be addressed.

3.11.7.10 Principal Spillway/Conduits - Any special embedding requirements for conduits that will penetrate the dam should be addressed. This would include concrete cradle requirements, filter collars, the need for camber in the pipe to accommodate settlement, and special backfill requirements adjacent to conduits. Allowable bearing pressures for outlet structures should be provided along with any special foundation preparation techniques appropriate for these areas.

3.11.7.11 Emergency/Open Channel Spillways - Items related to the excavation of any open channel spillways in the abutment areas should be addressed. The erodability index of materials exposed at the proposed finish grade should be determined for use in erosion calculations. The suitability of using excavated materials in the embankment, groundwater considerations, and the potential for difficult excavation should be considered. Armored spillway channels in abutment areas or on the embankment should provide details concerning seepage reduction and underdrainage system requirements.

3.11.7.12 Erosion Control - The need for shoreline wave protection, vegetative cover, berms, and protection of critical areas from surface runoff should be considered. Recommendations for positive erosion protection techniques such as riprap should include the bedding requirements for these materials.

3.11.7.13 Other Considerations - Any special requirements for items such as slurry walls, foundation grouting, and special consideration of the geology in which the site is located should be addressed in the geotechnical report. In essence, any geotechnical issues, which may impact the subsequent design and construction of the project, should be considered.

3.11.8 Instrumentation

Minimum instrumentation requirements should be included in this section. These recommendations should include types of instrumentation, locations, and the general approach to be used in monitoring and reporting the data.

3.11.9 Construction Monitoring

The report should address requirements related to the geotechnical evaluation and construction materials testing that will be required during construction. This includes the level of experience of the individuals responsible for testing and monitoring, general testing requirements, and identification of the specific areas that require monitoring. For large, high hazard dams, full-time monitoring of all phases of the construction is required.

3.11.10 Appendices

3.11.10.1 Supporting Data - All of the field and laboratory test results should be included as appendix items. Exploration location plans, subsurface profiles, boring records, laboratory test results, and any special details should be included.

3.11.10.2 Analyses - The actual calculations required for stability, seepage and settlement, as well as any other specific geotechnical calculations performed as part of the basis for the geotechnical study, should be included. This may be as an appendix item to the geotechnical report or may be submitted as a separate document along with the geotechnical study.

Hydrology
and
Hydraulics

Section 4
HYDROLOGY AND HYDRAULICS

4.1 Introduction

A spillway system must be capable of safely passing the runoff from the design storm event without the embankment overtopping and failing. The magnitude of the design storm depends on the hazard classification. A hydrologic analysis of the watershed and a hydraulic evaluation of the spillways are required to design an appropriate spillway system and determine the minimum crest elevation of the embankment.

The hydrologic analysis involves the computation of the runoff hydrograph. The hydraulic evaluation includes reservoir routing and the computation of elevation-discharge data for both the open channel and closed conduit spillways. Although this differentiation is not universal in civil engineering, it will be used in these guidelines.

Spillway design is an iterative process that involves routing the runoff hydrograph through the reservoir and a trial spillway system. The objective of this process is to design a spillway system that will safely pass the runoff from the design storm without overtopping the dam. Other objectives include designing a spillway system that is economical, dependable, and can be constructed with locally available materials.

The information in this section discusses some of the basic elements of a hydrologic and hydraulic analysis that the Project Engineer will find useful in designing or evaluating a spillway system for a dam. The methods referred to in this section are not exhaustive. Specific analytical methods should be determined on a case-by-case basis. Pre-design meetings between the engineer and the Division of Water are encouraged.

4.2 Hydrology

The design of a new spillway system and the evaluation of an existing spillway require the engineer to compute a runoff hydrograph. Parameters used in the computation of a runoff hydrograph include the watershed area, total rainfall, rainfall distribution (hyetograph), time of concentration, initial abstraction, and infiltration characteristics of the watershed.

4.2.1 Methodology

The runoff hydrograph, elevation-discharge data for the spillway system, and an appropriate reservoir storage-indication method of flood routing are used to perform an overtopping analysis of the dam. Flood routing is necessary to evaluate the adequacy of existing spillways and design new spillway systems. The overtopping analysis involves four steps: computing the runoff hydrograph, determining the elevation-discharge relationship for the spillway system (using the methods in Section 4.3), determining the elevation-storage relationship for the reservoir, and routing the runoff hydrograph through the reservoir and spillway(s). When designing a new spillway, iterations continue until the engineer determines an acceptable top-of-dam elevation and adequate size for both the principal and emergency spillways. Because of the iterative nature of the computations, engineers frequently utilize computer programs to perform hydrologic simulations. Acceptable computer programs include the United States Department of Agriculture (NRCS) DAMS2, SITES, and TR-20 software and the United States Army Corps of Engineers (COE) HEC-1 and HEC-HMS software.

4.2.2 Hazard Classification

The hazard classification of a dam is determined by evaluating the area that would be affected by inundation in the event the dam fails with the reservoir at the emergency spillway crest elevation or the dam crest elevation, in the absence of an emergency spillway. A correlation between the amount of inundation and the hazard classification is summarized in Appendix A. In many cases, the hazard classification of a dam can be determined by a review of current topographic maps and a visual inspection of the downstream floodplain for a distance commensurate with the size of the reservoir. If a breach analysis is required, the methodology described in Section 4.10 should be used.

Over time, development occurs in the area downstream of a dam. In fact, a manmade lake sometimes encourages downstream development. It is therefore prudent for the Project Engineer to consider designing the spillway for a higher hazard classification, when appropriate. This can help the owner avoid major dam and spillway modifications at a later date when the downstream development occurs, the hazard classification increases, and costs for upgrading the dam and spillway system are higher.

4.2.3 Design Storm Events

After the hazard classification of the dam has been determined, the appropriate design storm is selected using the criteria in Table 1.

If the time of concentration (Tc) is less than 6 hours, the 6-hour Probable Maximum Precipitation (PMP) should be used to analyze the spillway system. If the Tc exceeds 6 hours, the design storm duration is increased to a time equal to or greater than the Tc. This increases the PMP depth to account for the longer storm duration. All season 6-hour, 10 square mile PMP isohyetals and 24-hour, 10 square mile PMP isohyetals for the state can be found in Appendix D and in the latest edition of the Indiana Department of Natural Resources (IDNR) - Division of Water Publication "Rainfall Frequency for Indiana." The definition of the PMP rainfall event and its computation are discussed in the Department of Commerce Hydrometeorological Report (HMR) No. 52. If the watershed is greater than 10 square miles, the PMP depth may be reduced using procedures outlined in Hydrometeorological Report (HMR) No. 51.

Table 1: Design Storm Event for Spillway Design and Analysis

Dam's Hazard Classification	Design Storm Event	Remarks
High	100% PMP	For existing dams, a smaller design storm between 50% & 100% PMP may be justified through an elaborate Incremental Hazard Evaluation procedure described in TADS module "Evaluation of Hydrologic Adequacy".[1]
Significant	50% PMP	
Low	100-Year to 50% PMP	The spillway design storm requirements may vary from the 100-Year storm (for in-channel, low head dams which will be completely inundated by the 100-year storm event) to the 50% PMP (for normal situations, where the downstream hazard is likely to increase from low to significant in the future). A smaller percentage of PMP may be accepted by the Division of Water on a case by case basis, if the consequences of dam failure can be demonstrated to be negligible or assurance in the form of a deed restriction, covenant, etc. is provided to the Division of Water prohibiting new development within the dam breach inundation zone.

NOTE: [1] Information regarding this publication may be obtained from the Division of Water . The owner and engineer should recognize that dam construction typically results in higher risks. If an Incremental Hazard Evaluation procedure is utilized, the owner should periodically evaluate the downstream area to determine if this evaluation is accurate as new development takes place. The owner may eventually be required to modify the dam and spillway to safely pass the runoff from the 100% PMP, if such analysis indicates that the earlier results are no longer valid due to new development occurring downstream.

The 6-hour PMP hyetograph is derived using the NRCS Type B distribution while the 24-hour PMP hyetograph is derived using the NRCS Type II distribution. Both distributions are shown in Appendix D. Other rainfall distributions may be used to develop the design hyetograph. The Project Engineer is encouraged to meet with the Division of Water staff to discuss the use of other methods.

4.2.4 Watershed Area

Watersheds should be delineated on USGS 7½ minute topographic maps in accordance with recognized USGS delineations in the booklet, “Drainage Areas of Indiana Streams” to determine the size, shape and relief of the area contributing runoff to the reservoir. Watersheds are divided into sub-watersheds when appropriate (see http://in.water.usgs.gov/cdfactsheet/index.shtml) for use in delineating watershed boundaries. The engineer should consider dividing the watershed into sub-watersheds when the area above the dam is greater than 2000 acres or the sub-watersheds have significantly differing characteristics such as slope, land use, soil types, or shape.

4.2.5 Time of Concentration

There are numerous methods that can be used to compute the time of concentration. The size, shape, and geomorphology of the watershed are key factors that should be examined in detail before selecting a method. The surface runoff path should be divided into subreaches depending upon type of flow (sheet-overland, concentrated, gully, storm sewer, culver, ditch, stream, or channel), land cover, and slope. The kinematic wave method may be applied to calculate travel times from the point of entry into the lake, through the reservoir, and to the spillway outlet. Travel time calculations for each subreach should be provided and the total travel time indicated. Parameter limitations of each method should be examined before a method is selected. The following are a list of methods frequently used to compute the time of concentration:

- NRCS TR-55 Method (computes Tc directly by dividing the watershed into flow segments for both overland and channel flow; travel times for each segment are summed from the most hydraulically remote point in the watershed to the reservoir)
- NRCS Upland Method
- Kinematic Wave Method (computes Tc directly by dividing the watershed into flow segments for both overland and channel flow; travel times for each segment are summed from the most hydraulically remote point in the watershed to the spillway outlet)

Other Tc methods are acceptable. Documentation for the method used to determine the Tc should be included in the engineering report and should include the equation(s) and the design methodology (see Section 4.11).

4.2.6 Rainfall Losses

Initial abstraction and infiltration are deducted from the total rainfall to derive the runoff hydrograph. In the absence of site-specific data, lumped parameter models such as the NRCS Runoff Curve Number Method (*National Engineering Handbook*, Section 4, *Technical Release 5,* or *Engineering Field Handbook*, Chapter 2) can be used. The NRCS Runoff Curve Number Method is a methodology that determines losses and initial abstraction on the basis of soil types and land use. As a minimum, curve numbers should be determined for antecedent moisture condition (AMC) II. The engineer should consider projected land use changes in the computation of the curve number. Design documentation will include soil types, land use, maps, and the methodology used in calculating the curve number (see Section 4.11). The COE HEC-1 and HEC-HMS programs include other loss rate methods that are acceptable.

4.2.7 Hydrographs

Because smaller watersheds in Indiana are ungaged, the use of synthetic unit hydrographs is an accepted procedure for the computation of runoff hydrographs. Synthetic unit hydrographs are based on the assumption that watersheds within a homogeneous region have similar rainfall-runoff characteristics. The NRCS dimensionless unit hydrograph is typically used and is valid for watersheds up to 50 square miles in size. Larger watersheds can be divided into sub-watersheds less than 20 square miles in size to use the NRCS method. Clark's unit hydrograph, which considers the storage effects of the watershed, and Snyder's unit hydrograph, which considers the physical geometry of the watershed, are useful for analyzing larger watersheds. Snyder's method is valid for watersheds ranging in size from 10 square miles to 10,000 square miles. Other synthetic unit hydrographs may be acceptable but should be coordinated in advance with the Division of Water.

4.2.8 Channel Routing

Large heterogeneous watersheds are frequently delineated into sub-watersheds and stream networks. Runoff hydrographs are derived for each sub-watershed and channel routed through the stream network to the reservoir. The Modified Puls Method and the Muskingum-Cunge Method are typically used to perform the channel routing. The Muskingum-Cunge Method requires knowledge of the physical characteristics of the channel, such as the reach length, cross sections and slope to compute the routing coefficients. Both methods may be used with the HEC-1 or HEC-HMS programs to derive the runoff hydrograph for the watershed.

4.3 Hydraulics

Hydraulic calculations are performed to determine the elevation-discharge characteristics of closed conduit and open channel spillways. Principles of fluid mechanics allow the engineer to analyze weir, orifice and full pipe flow in closed conduit systems, which may include inlet structures, outlet structures, gates, and valves. Open channels are typically analyzed under steady, nonuniform flow conditions to determine the location of the control section and the water surface profile. Transitions from gradually varied flow to rapidly varied flow frequently occur in open channels and the analysis should evaluate the effect of side channel entrances, ogee sections, bridges, geometric transitions, and energy dissipation structures.

4.3.1 Spillways

The design of spillways for a dam project requires consideration of numerous parameters. Among these parameters are the type, size, and location of primary and emergency spillways and the need for inlet and outlet structures. The topography and soil conditions at a site are important considerations in the design of spillway systems. The need for energy dissipation, erosion control, debris protection measures, and maintenance procedures should be evaluated.

Typically, a dam will have at least two spillway structures, a principal (or primary) spillway and an emergency (or auxiliary) spillway. The combined capacities of the spillways should be able to safely pass the runoff from the design storm without overtopping the dam. The emergency spillway should be an engineered open channel to prevent blockage during the design flood.

Due to the high maintenance costs and the erosion potential of grassed open channel spillways, it is desirable to minimize the frequency of use of the emergency spillway. A typical approach is to design the spillway system so that the emergency spillway only operates for rainfall events greater than the 100-year event. For significant and low hazard structures, the emergency spillway should only operate for rainfall events greater than the 50-year storm.

The emergency spillway (regardless of the type) should be properly protected against erosion in order to provide structural resistance to up-lift, cavitation, vibration, and erosion. Sufficient erosion protection should be provided to prevent the uncontrolled release of reservoir storage below the emergency spillway elevation during the design flood.

4.3.1.1 Principal Spillway

The principal (or primary) spillway controls the normal pool elevation of the lake and should safely handle outflow from the lake under various conditions including freeze/thaw and ice buildup. The principal spillway usually consists of an inlet structure, a closed conduit, and an outlet structure. Ease of access for timely maintenance is especially critical. Principal spillways are frequently located within the embankment although they may be situated in natural ground. Some types of principal spillways include:

- Culvert(s)
- Drop Structures
- Gated Structures
- Labyrinth Weirs
- Morning Glory Inlets
- Ogee Weirs
- Standard Covered Risers

Public safety should be considered in the design of principal spillway inlets and outlets. Barriers should be placed on riser openings and signs posted near inlet structures to warn the public of the hazard posed by spillways.

4.3.1.2 Emergency Spillway

The emergency (or auxiliary) spillway provides additional discharge capacity as the lake level rises to prevent the dam from overtopping during the design storm. The emergency spillway also provides an alternative for safe discharge should the primary spillway become inoperable or blocked.

The outlet slope of the emergency spillway should be greater than the critical slope to cause critical depth (a hydraulic control section) to occur at the spillway crest. Backwater computations should be submitted for a wide range of discharges in order to establish a rating curve and show the depth-discharge characteristics for the entire length of the spillway. Regardless of the spillway slope, it is advisable to compute a water surface profile for the design discharge using the Corps of Engineers HEC-RAS or HEC-2 programs to estimate the maximum velocities in the channel and determine the height of erosion protection required in the spillway.

The emergency spillway is typically an open channel. It should be located in natural ground away from the dam so that during the operation of the spillway, the dam will not be endangered. When this is not feasible, adequate armor protection should be placed on the dam to allow a portion of it to act as an emergency spillway during the design storm. Emergency spillways in natural ground are typically vegetated but may need additional protection if operated frequently or if design flow velocities are excessive. Listed below are types of acceptable armor protection for emergency spillway channels:

- Articulated Blocks
- Concrete Paving
- Gabion Baskets (underlain with a properly designed filter)
- Engineered Riprap

Early coordination with the Division of Water is required when an emergency spillway will be located on the embankment.

4.3.2 Spillway Rating Curves

A rating curve (plot of elevation versus discharge) should be developed for each primary and emergency spillway structure. The rating curves should be combined into an overall rating curve for the reservoir. The engineer should evaluate how the different spillway structures will affect the overall outflow capacity and the ability of the spillway system to safely pass runoff from the design storm.

Design documentation should include the equations used to calculate each of the spillway rating curves and the design methodology. The rating curves should be provided in tabular and graphical format (elevation-discharge tables) for each of the spillway structures and combination of all structures.

Maximum design flow velocities for the principal and emergency spillways should be computed when designing structures, outlets, and channels. An evaluation of the maximum velocities is necessary to determine if stilling basins or other outlet protection is required. The design of suitable energy dissipation measures is an important consideration for each spillway structure

4.3.2.1 Downstream Channel Conditions

Channel conditions downstream of the dam can greatly affect the discharge capacity and stability of the dam and should be considered in the overall design. In situations where there are restrictions in flow capacity downstream of the dam (due to a roadway culvert, bridge, lake, levee, or a narrow valley cross-section), the restrictions should be evaluated to determine if tailwater conditions exist at the dam and if the tailwater will reduce the capacity of the spillways.

Typical stilling basin and plunge pool energy dissipation designs require that the tailwater elevation for the channel downstream of these structures be known.

The methodology and data required for determining tailwater conditions at spillway outlets can vary depending upon the characteristics of each downstream restriction. Appropriate field data should be obtained for each downstream restriction, in order to accurately determine the resulting tailwater effects. Corps of Engineers programs HEC-RAS and HEC-2 are typically used to calculate backwater profiles for determining tailwater effects. Other methods or software may be acceptable with prior approval from the Division of Water

4.3.3 Force and Energy Considerations

The operation of spillway structures involves the discharge of significant flows for an extended period of time. In the event the forces and energy resulting from flow through the spillway structure are not considered in the selection and design of spillway structures, damage or failure of the structure may occur. This could impact the overall safety and integrity of the dam.

Structural analysis is necessary to determine the effect of momentum forces on the spillway structures during the design storm. The results of the analysis are used to design the structures to withstand these forces. Analysis and design to provide adequate energy dissipation at each spillway outlet is also necessary. Listed below are some types of energy dissipators.

4.3.3.1 Conduit Spillway Energy Dissipators

- Cantilever Plunge Pool
- Impact Basin
- Riprap Basin
- Stilling Basin (with blocks and end sill)
- Chute Blocks

4.3.3.2 Concrete Chute Spillway Energy Dissipators

- Deflector Buckets
- Hydraulic Jump Basin
- Stilling Basin

Earthen emergency spillways are subject to erosion and possible failure during the design storm. If the failure of an earthen emergency spillway could affect the safety or integrity of the dam, or pose a hazard to downstream residents and structures, spillway attack calculations should be provided. These calculations predict the likelihood that an earthen spillway will fail during the design storm based on soil resistance and bulk length. Field and laboratory data should be obtained to perform the spillway attack calculations so that the spillway can be designed to perform safely. The NRCS SITES computer program may be used to assess the erodibility of an earth spillway.

Structural analysis and geotechnical evaluations regarding spillways should be incorporated into the structural design section of the engineering report and submitted with the permit application.

4.4 Reservoir Routing Procedures

The elevation-storage characteristics of the reservoir should be determined from a hydrographic survey of the reservoir, USGS topographic maps, or maps derived from aerial photography. The elevation-storage data should be submitted in both graphical and tabular format.

After the runoff hydrograph, the elevation-storage curve, and the combined spillway-rating curve have been derived, the engineer can perform reservoir routing computations. Reservoir routing refers to the iterative process of balancing inflow volume, outflow volume, and available storage volume for incremental time periods over the duration of the design storm event in order to assess performance characteristics of the reservoir. The Modified Puls reservoir routing method is typically used to route the runoff hydrograph from the watershed through the reservoir and spillway system. Alternatives for various configurations of the dam and spillway system should be evaluated to design a cost effective principal and emergency spillway that will be dependable and safe.

4.5 Freeboard Calculations

All spillway systems must safely pass the design storm without overtopping the dam. The characteristics of the reservoir should be evaluated to determine if freeboard is required. Freeboard is defined as the distance between the maximum elevation of the reservoir during the design storm and the minimum elevation of the dam crest. In certain situations, the length and orientation of the reservoir may increase the height of waves during the design storm. These waves could overtop the dam. The engineer should determine the effects of wave action when appropriate.

On rare occasions, a dam may be designed to allow overtopping to occur during the design storm. Because of the complexity and risk involved in designing a dam to withstand overtopping, the Project Engineer should meet with the Division of Water staff early in the preliminary engineering phase to discuss specific design requirements.

4.6 Structural/Mechanical

Spillway structures, gates, valves, and appurtenant works should be designed to operate efficiently and safely handle all expected flows (normal & infrequent) and loading conditions from the dam. Spillway structures should be designed to allow maintenance and repairs to be accomplished throughout the expected life of the dam.

4.7 Filling Schedule for Reservoirs

In some cases, it may be necessary to fill the reservoir in stages to allow time for the embankment and foundation materials to adjust to the increased hydrostatic loads resulting from the reservoir. A schedule for filling the reservoir should be developed, based on the embankment and foundation performance, as determined by properly installed instrumentation and visual inspections. The following is a typical schedule for filling the reservoir:

- First 1/3 of the pool level – fill rate unrestricted
- Second 1/3 of pool level - no more than 2 feet per week
- Final 1/3 of pool level - no more than 1 foot per week

4.8 Drawdown Time

All dams should have an adequately designed drawdown structure to allow maintenance and accommodate the requirements of the Operation Plan and the Emergency Action Plan. The dam owner should consider the affects of downstream flooding during reservoir drawdown operations

Rapid drawdown situations affect the stability of the embankment and should be considered when designing the dam and lowering the pool. The rate of safe drawdown and the capacity of the drawdown pipe should be computed by the engineer and documented in both the Operation Plan and the Emergency Action Plan.

4.9 Spillway Materials

Proper selection and design of materials for a spillway system are as important as the capacity. Metal, concrete, riprap, geosynthetics, and high-density polymers are some of the materials available for spillway structures. The anticipated loads, required operations, expected performance, life cost, and the spillway environment should be considered in the selection of spillway materials.

Materials for pipe spillways should be selected carefully. Pipe spillways are designed for pressure flow. Corrugated metal pipe (CMP) joints are not designed to be watertight in high-pressure applications and are not recommended for use in spillway systems. Welded steel pipe is acceptable in low-head applications but cathodic protection should be provided to delay the onset of corrosion. Because of construction issues, past failures, and the lack of long-term performance documentation in spillway applications, the use of polyvinyl chloride (PVC) and high-density polyethylene (HDPE) pipes are not recommended for spillway pipes. Reinforced concrete pipe (RCP) is very durable and is typically used in pipe spillways. Bell and spigot joints with rubber o-ring gaskets provide a watertight joint in most RCP applications. The use of anti-seep collars and/or seepage control diaphragms should be included in the design and construction of conduit spillways through dams.

4.10 Hazard Evaluation and Dam Break Analyses

Properly designed, constructed, and operated dams can be expected to attenuate downstream discharges during flood events. However, failure of a dam during normal conditions or during a flood event can create a potential hazard far greater than that which existed without the dam. The consequences of dam failure should be fully evaluated and analyzed in order to properly identify and define the extent of the potential "hazard zone". The results of these analyses should be used in determining the hazard classification of the dam and developing the Emergency Action Plan procedures.

4.10.1 Dam Break Analysis Methods

The degree of study required to define the impacts of potential dam failures is site specific and will vary depending upon the type and height of dam, size of reservoir, and downstream conditions. In some cases, detailed studies referred to as, "dam break" or "dam breach" analyses, will be required to determine the anticipated downstream hazard zone.

The generally accepted procedure for dam break analysis involves application of unsteady flow and dynamic routing methods. The following computer programs apply this procedure:

- DAMBRK (National Weather Service)
- FLOODWAV (National Weather Service: combines the DAMBRK model with the DWOPER model)

The Corps of Engineers HEC-1 hydrologic model may also be used to perform a dam break analysis to determine downstream inundation areas. The HEC-1 dam break simulation assumes that the reservoir pool remains level while water is released through an incrementally changing triangular, rectangular, or trapezoidal breach in the dam. The HEC-1 model can be used with a river routing scheme to delineate downstream flood zones or in conjunction with the COE HEC-RAS or HEC-2 models to simulate steady, nonuniform flow conditions in the downstream channel and floodplain. When the COE models are used, the hydrologic methods are assumed to be appropriate for the dynamic flood wave. Under most conditions, these assumptions will be approximately true and will provide results that are sufficiently accurate for the determination of the downstream hazard zone. Appropriate care is recommended in interpreting the results of a dam break analysis based on these assumptions. If a higher order of accuracy is necessary, the National Weather Service unsteady flow models should be applied.

4.10.2 Dam Break Analysis Parameters

The accepted methods for determining dam break analysis scenarios require the user to select the dam failure parameters under a variety of failure modes. Table 2 provides typical values for these parameters. The parameters include the size, shape, and time of formation of the dam breach.

The conditions during which the simulated dam breach occurs is a critical component of the analysis. A "sunny day" breach analysis implies that the dam fails as a result of structural, geotechnical or mechanical failure, not as a result of overtopping of the dam. However, it is advisable, when performing a sunny day breach analyses, to assume (at a minimum) that the reservoir pool elevation is at the emergency spillway operating elevation. In the event that the reservoir does not have an emergency spillway or other open channel spillway outflow, the reservoir elevation should be considered to be at the minimum dam crest elevation.

Simulation of a dam break during the design storm is also advisable. This analysis should be considered in situations where there is the potential that the spillway system capacity could be significantly reduced as a result of blockage, operating failure, or some other condition. This dam break scenario assumes that the failure will occur as soon as the reservoir elevation exceeds the minimum dam crest elevation. Careful consideration should be given to the amount of inflow, the reservoir elevation at failure, and the downstream water elevation. If a recent storm event has occurred, downstream conditions may still be fully saturated or at a flood level.

When analyzing a sunny-day breach or a dam break during the design storm event, the flood storage provided by downstream dams may be considered by the engineer if these dams are approved by the state and regularly inspected. If a downstream dam is not approved by the Division of Water or if an approved downstream dam is found to overtop, the water stored by the dam is assumed to be released and included in the analysis.

Table 2: Suggested Breach Parameters for Indiana

Type of Dam	Avg. Breach Width BR (feet)	Breach Side Slope Z	Time to Failure TFH (Hours)
Arch	W	Vertical or Slope of Valley Walls	0.1
Masonry; Gravity	Monolith Width	Vertical	0.1 to 0.3
Rockfill	HD	---	---
Timber Crib	HD	Vertical	0.1
Slag; Refuse	80% of W	1.0 to 2.0	0.1 to 1.0
Earthen "non-engineered"	2HD to 5HD	0.0 to 1.0	0.1
Earthen "engineered"	0.5HD to 5HD	0.0 to 1.0	0.5 to 1.0

Definitions:
- BR Average Width of Breach
- HD Height of Dam
- TFH Time of Full Formation of the Breach
- W Crest Length
- Z Horizontal Component of Side Slope of Breach

4.11 Documentation

The hydrologic and hydraulic design and analysis of a dam consists of extensive technical work. The engineering report should clearly document the programs, assumptions, parameters, equations, tables, graphs, methodology, engineering judgement, results, and recommendations that were used in the evaluation process. When computer programs are used to perform hydrologic and hydraulic computations, copies of the data files should be submitted in electronic format (floppy disk or CD). The engineering report should be submitted with the permit application to facilitate the review and approval process.

Drawings
and
Specifications

Section 5
DRAWINGS AND SPECIFICATIONS

5.1 Introduction

Every proposed dam or dam repair project requires a set of complete drawings (also referred to as plans) and specifications tailored to the project.

The drawings and specifications are based on the results of the technical evaluations (hydrologic/hydraulic, geotechnical, geologic, structural, etc.) described in the previous sections and recommendations in the engineering report. This section lists items which typically are included in a set of drawings and specifications submitted to the Division of Water. This is not intended to be an all-inclusive list, nor will all of these items be required for every project. This list is limited to aspects of the dam and appurtenant structures. Other items such as an erosion control plan and a plan addressing archeological and cultural resources may need to be submitted for review by others. Some of the items in this section may be combined for clarity or simplicity.

Selected plan sheets for an example dam have been included in Appendix E to illustrate the level of detail and completeness required for small to medium size dams. In Appendix F is a list of the Common Pitfalls that render plans and specifications incomplete.

5.2 Construction Drawings Guidelines

It is recommended that drawings be submitted on 24” X 36” sheets.

5.2.1 Title Sheet

5.2.1.1 Location map with North arrow and scale
5.2.1.2 List of drawings
5.2.1.3 Twenty-four (24) hour contact and phone number
5.2.1.4 Owner's name, address, and phone number
5.2.1.5 Engineer's name, address, and phone number
5.2.1.6 Engineer's professional seal
5.2.1.7 Legend & Information

5.2.2 Regional Plan

5.2.2.1 Regional features that the contractor should be aware of during construction (i.e. drainage area, upstream dams, etc.)
5.2.2.2 Location of proposed lake and dam
5.2.2.3 Downstream hazards (buildings, road, etc.) potentially impacted by dam breach

5.2.3 Vicinity Plan

5.2.3.1 Excavation within the area upstream from the toe of the dam should be based on safety considerations. The Project Engineer usually determines the limits of excavation.
5.2.3.2 Disturbance limits
5.2.3.3 Existing topography
- source (aerial, ground survey, data source)

5.2.3.4 Existing features
5.2.3.5 Borrow/spoil areas
5.2.3.6 Property/easement limits and owners/easement holders
5.2.3.7 North arrow and scale
5.2.3.8 Demolition

5.2.4 Site Plan

5.2.4.1 Site grading
5.2.4.2 Existing topography
- source (i.e. aerial, ground-run, data source)
- contour interval 2-5 ft suggested.

5.2.4.3 Existing features
5.2.4.4 Borrow/spoil areas
5.2.4.5 Disturbance limits
- should be based on safety considerations.

5.2.4.6 Property/easement limits and owners/easement holders
5.2.4.7 Proposed structures, spillways and features
5.2.4.8 Demolition
5.2.4.9 North arrow and scale
5.2.4.10 Geotechnical exploration locations
5.2.4.11 Survey control points

5.2.5 Profiles and Sections

5.2.5.1 Dam centerline profile
- subsurface soils/rock borings
- crest profile (showing compensation for settlement)
- seepage collection and drainage features

5.2.5.2 Dam cross sections
- foundation preparation
- embankment zoning
- upstream and downstream slopes
- seepage collection and drainage features
- cut off trench
- roadway on crest

5.2.5.3 Emergency spillway profile
- typical section
- cross sections
- training berm profile

5.2.5.4 Principal spillway profile
- conduit camber
- anti-seep collar
- seepage control diaphragm

5.2.5.5 Seepage reduction
- clay blanket
- keyway
- slurry wall
- grout curtain
- other relevant items

5.2.6 Seepage Collection

5.2.6.1 Drain Types
- chimney drains
- blanket drains
- trench drains
- toe drains
- foundation drains
- filter collar drains
- rock toes
- other

5.2.6.2 Drain Plans

5.2.6.3 Drain Profiles and Sections

5.2.6.4 Drain Details
- outlet headwalls
- cleanouts
- collection pipe
- animal guards

5.2.7 Instrumentation Plan

5.2.7.1 Settlement plate locations

5.2.7.2 Piezometer locations

5.2.7.3 Instrumentation details (as needed)

5.2.7.4 Installation details (as needed)

5.2.8 Structural Plans

5.2.8.1 General Plans

5.2.8.2 Structural sections and details

5.2.8.3 Waterstop details

5.2.8.4 Concrete joint details and locations

5.2.8.5 Trash rack details
5.2.8.6 Spillway slab
- underdrains
- anti-cavitation details

5.2.8.7 Outlet pipe and concrete cradle details
- filter collar

5.2.8.8 Intake structure details
5.2.8.9 Retaining wall
- foundation
- wall drain

5.2.8.10 Lake drawdown pipe

5.2.9 Miscellaneous Details

5.2.9.1 Shoreline wave protection
5.2.9.2 Internal drainage outlet
5.2.9.3 Plunge pool details
5.2.9.4 Rip-rap details
- limits
- thickness
- type
- bedding
- geotextile

5.2.9.5 Gates & Valves
5.2.9.6 Pavement Details

5.3 Construction Specification Guidelines

5.3.1 Site Preparation

5.3.1.1 Reservoir clearing
5.3.1.2 Clearing and grubbing
5.3.1.3 Waste disposal
5.3.1.4 Stripping
5.3.1.5 Demolition

5.3.2 Dewatering and Diversion

5.3.2.1 Diversion of water
5.3.2.2 Removal of water

5.3.3. Earthwork

5.3.3.1 Undercutting
5.3.3.2 Excavation

5.3.3.3 Rock removal
5.3.3.4 Borrow area development
5.3.3.5 Fill material placement
- Compaction
5.3.3.6 Backfilling
5.3.3.7 Rock fill

5.3.4 Foundation Treatment

5.3.4.1 Drilling and pressure grouting
5.3.4.2 Slurry trench
5.3.4.3 Keyways
5.3.4.4 Treatment of rock surface
5.3.4.5 Rock anchors

5.3.5 Conduits

5.3.5.1 Reinforced concrete pressure pipe
5.3.5.2 Reinforced concrete pipe
5.3.5.3 Steel pipe
5.3.5.4 Ductile iron pipe
5.3.5.5 PVC siphon pipe
5.3.5.6 HDPE pipe

5.3.6 Seepage Collection Systems

5.3.6.1 Toe drains
5.3.6.2 Blanket drains
5.3.6.3 Chimney drains
5.3.6.4 Trench drains
5.3.6.5 Foundation drains
5.3.6.6 Filter collars
5.3.6.7 PVC drain pipe
5.3.6.8 Aggregates
5.3.6.9 Geotextiles

5.3.7 Erosion Protection

5.3.7.1 Rip-rap
5.3.7.2 Geotextiles
5.3.7.3 Other
5.3.7.4 Articulated block

5.3.8 Grassing and Vegetation

- 5.3.8.1 Soil preparation
- 5.3.8.2 Seeding
- 5.3.8.3 Mulching

5.3.9 Fencing

- 5.3.9.1 Fence
- 5.3.9.2 Gates

5.3.10 Instrumentation

5.3.11 Concrete

- 5.3.11.1 Formwork
- 5.3.11.2 Reinforcement
- 5.3.11.3 Accessories
- 5.3.11.4 Cast-in-place concrete
- 5.3.11.5 Precast concrete
- 5.3.11.6 Roller compacted concrete
- 5.3.11.7 Waterstops
- 5.3.11.8 Joint material

5.3.12 Metals

- 5.3.12.1 Trash rack
- 5.3.12.2 Structural steel
- 5.3.12.3 Miscellaneous metals
- 5.3.12.4 Anchor bolts
- 5.3.12.5 Handrails

5.3.13 Equipment

- 5.3.13.1 Sluice gate
- 5.3.13.2 Valves
- 5.3.13.3 Weirs
- 5.3.13.4 Other

Construction Monitoring

Section 6
CONSTRUCTION MONITORING

6.1 Introduction

The best embankment and spillway design can turn out to be a failure without proper construction monitoring. It is critical that the Project Engineer adequately monitor the construction of the dam and the initial filling of the reservoir. It is also important to monitor the performance of the dam following the completion of construction.

6.1.1 Construction Versus Post Construction

The monitoring program for the construction of a new dam, or the remediation of an existing dam, includes both the actual construction work and the initial reservoir filling (refilling). This section of the guidelines deals primarily with the actual construction period.

6.1.2 Project Engineer and other Technical Professionals

The Project Engineer should work closely with the owner and remain involved with the project during construction. As the owner's representative, the Project Engineer should make regular visits to the site. For large projects, the Project Engineer may designate a field engineer to remain on site and monitor all construction work. In most instances, a geotechnical engineer will be actively involved with the project for the design firm, or as a subconsultant to the design firm. The geotechnical engineer will perform many of the construction monitoring activities. A senior geotechnical technician may be assigned to deal with many of the routine aspects of construction such as monitoring clearing and grubbing activities, monitoring foundation preparation, and performing compaction testing, concrete testing, and gradation tests of the filter and drain material. In addition, other engineering disciplines may be involved in project management and structural evaluations.

6.1.3 Level of Involvement

For large projects, the construction operations should be monitored on a full-time basis. The appropriate design engineer should monitor the construction work that will remain part of the completed project. Many of the construction activities require meeting not only minimum performance requirements, but also observing the details of the actual construction. For example, monitoring the earthwork requires more than density testing which provides only an indication of the degree of compaction and the in place moisture content of the fill material. It is important to monitor the placement of the materials in the dam to make sure lift surfaces are properly prepared and material is placed in the zones depicted on the design plans. This can only be determined by full-time observation of the construction activities.

6.1.4 Need for Technical Professional Involvement

Design activities continue through the construction phase. Interpretations of subsurface data, constructability issues, and modifications necessitated by the contractor's experience and equipment mandate that representatives of the design team remain involved throughout the construction process. These individuals are most familiar with the design assumptions and are in the best position to recommend appropriate modifications, if needed.

6.1.5 Adherence to Plans and Specifications

The primary function of the construction monitoring team is to verify that the contractor complies with the approved plans and specifications.

6.1.6 Design Changes/Field Conditions

Situations occasionally occur where the design will need to be altered due to unforeseen field conditions. The Project Engineer can help facilitate a quick resolution to these situations. Changes that are significant will need to be reviewed and approved by the Division of Water prior to the change being implemented. Minor modifications should be reported and documented on the as-built drawings.

6.1.7 Certification

Almost all permits on dams include a condition that requires the applicant to submit as-built plans certified by a professional engineer. The Project Engineer needs to be closely involved in the construction activities to be able to provide such a certification.

6.2 Routine Construction Monitoring Reports

The following is a brief listing of several of the aspects of construction monitoring that typically need to be performed. This should not be considered an all-inclusive list and should be amended or expanded to account for the particular dam being built. Ideally, all aspects of the construction phase should be monitored and reported.

6.2.1 Clearing and Grubbing

The Project Engineer should evaluate the site after the contractor has completed the clearing and grubbing operations to determine that adequate procedures have been followed to allow for subsequent construction. This monitoring should be reported in a daily inspection report.

6.2.2 Subgrade

The Project Engineer should monitor the subgrade and foundation preparation for the dam. This involves items such as stripping, undercutting of unsuitable material (particularly flood plain undercutting), and keyway/cutoff construction. The conditions observed, including items such as depths of excavation and quantities should be documented in the daily field reports. The geotechnical engineer should approve all subgrade areas before fill placement occurs.

6.2.3 Drains

The Project Engineer should monitor all aspects of the internal drain system construction. The internal drainage system may include a number of components such as foundation drains, blanket drains, chimney drains, and collections systems. Since these systems are filtered either with natural materials or synthetic materials, the monitoring should assure that all filters completely enclose more pervious materials, and that the drains extend into the desired material for the proper control of the phreatic surface. Field adjustments to the drain construction are common and should be documented in daily monitoring reports.

6.2.4 Outlet Works

The Project Engineer should monitor the construction of spillway and drawdown pipes, and their associated intake and outlet structures. Intake control structures typically require assessment of allowable bearing capacity and adequate subgrade preparation. Outlet structures commonly incorporate some underdrainage. Conduit alignments may include concrete anti-seepage cradles, as well as filtered seepage collars. The engineer should monitor the configuration of excavations for conduits, and closely assess all backfilling procedures adjacent to this critical area of the dam. Density tests and concrete tests should be conducted and reported. The geotechnical engineer should approve all subgrades for cradles and structures for subsequent construction.

6.2.5 Earthwork

The geotechnical engineer or a qualified representative should monitor all aspects of the earthwork operations on a full time basis. Routine density testing and moisture control should be reported. In addition, the construction techniques utilized by the contractor should be reported and evaluated to assure conformance with the project specifications. The engineer's representatives should verify that all materials placed in the embankment are suitable for their intended use and that proper lift treatment is performed by the contractor to assure adequate bonding of the individual lifts. The engineer's representatives will determine if moisture adjustments are needed at the fill pad prior to fill placement. This may include either wetting or drying the borrow material to achieve suitable moisture content. The engineer's representatives should assure that the contractor is using appropriate equipment in the grading activities. Reporting would typically include daily inspection reports summarizing the grading activities and the individual density test report.

6.2.6 Instrumentation

The details of the instrumentation program are outlined in Appendix C. Instrumentation may be placed during the construction process or at the completion of the general embankment construction. In many instances, instrumentation will include devices that are intended to be read during the construction process. For example, settlement plates or devices placed at the base of the dam are typically read throughout the construction process. The engineer should observe the installation of all instrumentation, and evaluate data collected during construction. The data should be compared to design projections to determine if any modifications or further assessments are needed.

6.2.7 Construction Photographs

It is considered good practice to take photographs or video recordings of critical aspects of the construction. These may be in the form of regularly scheduled photographs of the work progress, or specific photographs of certain aspects of the construction. The intent is to obtain a permanent record should any difficulties arise during initial reservoir filling or during subsequent operation of the dam. Photographs should be adequately labeled and dated, and are typically maintained in the design engineer's file. In certain instances, copies should be provided to the Division of Water to document unusual situations.

6.3 Special Construction Monitoring Reports

There may be situations where special construction monitoring is needed and the collection and presentation of information is required. Guidelines are presented in Appendix G. In applying these guidelines, the Project Engineer should use good judgement and elaborate upon them as required by the particular geologic/foundation setting and engineering requirements. These guidelines are not intended to be exhaustive and include all items contained in a special report. However, they do provide guidance to formulate a data acquisition program for planning and documenting specialized work.

6.4 Post Construction Monitoring

The purpose of the post construction monitoring program is to provide information regarding the behavior of the constructed or rehabilitated dam. This information is used in conjunction with as-built drawings and construction photographs to evaluate the performance of the newly constructed dam and to compare to historical data for an existing dam. The recorded data is compared to design assumptions for the dam in order to monitor lake filling and provide a means for future monitoring, operations, and maintenance.

6.4.1 As-Built Drawings

A set of as-built drawings should be submitted to the Division of Water following completion of construction and within the time limits specified in the permit. The as-built drawings should include, as a minimum, the following:

6.4.1.1 Approved Modifications - All previously approved design and construction modifications should be incorporated into the final document.

6.4.1.2 Monitoring Program - A monitoring and instrumentation program should be described if one is required.

6.4.1.3 Acceptance Criteria - A list of critical design assumptions and expected behaviors that need to be validated initially and long term should be included.

6.4.1.4 Instrumentation Locations - The location of all post construction monitoring instrumentation should be shown on the as-built site plan.

6.4.1.5 Certification - A written certification from the Project Engineer that the dam was constructed as shown on the as-built plans.

6.4.2 Lake Level

After approval by the Project Engineer, the reservoir drawdown valve may be closed and the process of filling the lake may commence. Adherence to the reservoir-filling schedule should be controlled by operation of the outlet works in order to maintain the differential rise in Lake Level and maintain flow (see Section 4.7). In the event that sudden changes occur which may be indicative of a potential dam failure, the lake level should be lowered and the Division of Water notified immediately. Otherwise, after the lake reaches the normal operating level, the approved maintenance, inspection and operation plan should be initiated.

6.4.3 Physical Condition of Dam

Areas of potential weakness and their effects on dam stability should be identified. Visual observations should be made in conjunction with instrumentation monitoring to adequately assess the safety of the dam. Initial surveillance of the dam's performance should be conducted by the Project Engineer to confirm design assumptions and to evaluate performance. Many unusual or abnormal conditions can be identified by a walking tour of the dam crest, slopes, toe, and abutments. Long-term inspection, operation, and maintenance will be the responsibility of the dam owner.

6.4.4 Instrumentation Readings

Readings that are commonly monitored at a dam site include headwater and tailwater levels, porewater and uplift pressures, crack or joint movement, structural movement, deformation, seepage flow rates, stress and strain of structural members, temperature, and seismic loads. A monitoring and instrumentation program that assigns responsibility to the engineer for data collection, reduction, presentation, and transmittal to Division of Water staff may need to be developed and documented. The program should include the reasons for installation, frequency of monitoring, threshold ranges of instruments, installation logs, calibration data, and initial readings.

All data should be compared with design assumptions for the expected behavior of the dam. If no unusual behavior or evidence of problems is detected, the readings should be maintained for future reference. Threshold readings that indicate the development of potentially hazardous conditions should be established. Action should be taken if the data deviates from expected behavior or approaches the threshold readings, depending on the nature of the potential hazard. Possible actions include:

- Performing detailed visual inspection
- Repeating measurements to confirm behavior
- Notifying the owner's engineer and the Division of Water
- Increasing frequency of measurements
- Designing and constructing remedial measures
- Installing additional instrumentation
- Operating the reservoir at a lower level
- Implementing emergency measures

6.4.5 Photographs

Photographs or videos are useful in documenting the initial site investigation, subsurface excavation, construction, and as-built conditions. They are helpful for providing a historical perspective in evaluating whether or not there has been any change from previous conditions. Photographs and videos should be maintained for future reference in the event remedial or emergency action is required.

Appendix A
Hazard Classification

Revised - February 2010

Rule 3 - Hazard Classification

312 IAC 10.5-3-1 Consideration of hazard classification

Authority: IC 14-27-7.5-8

Affected: IC 14-27-7.5

Sec. 1 (a) The division shall assign whether a dam is classified as:

(1) high hazard;

(2) significant hazard; or

(3) low hazard;

based on best information available.

(b) In making the determination of assignment under subsection (a), the division shall apply existing U.S. Army Corps of Engineers Phase 1 reports and other appropriate documentation.

(c) The division may also consider observations of the dam and the vicinity of the dam, including the risk posed to human life and property if the dam fails.

(1) If an uncontrolled release of the structure's contents due to a failure of the structure may result in any of the following, the dam shall be considered high hazard:

(A) The loss of human life.

(B) Serious damage to:

(i) homes;

(ii) industrial and commercial buildings; or

(iii) public utilities.

(C) Interruption of service for more than one (1) day on any of the following:

(i) A county road, state two-lane highway, or U.S. highway serving as the only access to a community.

(ii) A multilane divided state or U.S. highway, including an interstate highway.

(D) Interruption of service for more than one (1) day on an operating railroad.

(E) Interruption of service to an interstate or intrastate utility, power or communication line serving a town, community, or significant military and commercial facility, in which disruption of power and communication would adversely affect the economy, safety, and general well-being of the area for more than one (1) day.

(2) If an uncontrolled release of the structure's contents due to a failure of the structure may result in any of the following, the dam shall be considered significant hazard:

(A) Damage to isolated homes.

(B) Interruption of service for not more than one (1) day on any of the following:

(i) A county road, state two-lane highway, or U.S. highway serving as the only access to a community.

(ii) A multilane divided state or U.S. highway, including an interstate highway.

(C) Interruption of service for not more than one (1) day on an operating railroad.

(D) Damage to important utilities where service would be interrupted for not more than one (1) day, but either of the following may occur:

(i) Buried lines can be exposed by erosion.

(ii) Towers, poles, and aboveground lines can be damaged by undermining or debris loading.

(3) If an uncontrolled release of the structure's contents due to a failure of the structure does not result in any of the items given in subdivision (1) or (2) and damage is limited to either farm buildings, agricultural land, or local roads, the dam shall be classified as low hazard.

(d) The division may modify an assignment of hazard classification, made previously under this article, if changes in the downstream development affect the potential for loss of human life and property. (Natural Resources Commission; 312 IAC 10.5-3-1; filed Jan 26, 2007, 10:45 a.m.: 20070221-IR-312060092FRA)

312 IAC 10.5-3-2 Reconsideration of hazard classification

Authority: IC 14-27-7.5-8

Affected: IC 14-27-7.5

Sec. 2 (a) This section establishes a process by which a dam owner or another affected person may request reconsideration of a determination of hazard classification made under section 1 of this rule.

(b) The dam owner or other affected person may submit any technical information or reports that were not previously available to the division.

(c) The dam owner's or other affected person's professional engineer may develop and submit a maximum breach inundation area and current damage evaluation assessing the downstream area affected by a dam breach.

(1) If the maximum breach inundation area and current damage evaluation predicts any of the following, the dam shall be classified as high hazard:

(A) Flood depths greater than one (1) foot in any occupied quarters.

(B) Loss of human life may occur.

(C) Interruption of service for more than one (1) day on any of the following:

(i) A county road, state two-lane highway, or U.S. highway serving as the only access to a community.

(ii) A multilane divided state or U.S. highway, including an interstate highway.

(D) Interruption of service for more than one (1) day on an operating railroad.

(E) Damage to any occupied quarters where the flow velocity at the building compromises the integrity of the structure for human occupation.

(F) Interruption of service to an interstate or intrastate, utility, power or communication line serving a town, community, or significant military and commercial facility, in which disruption of power and communication would adversely affect the economy, safety, and general well-being of the area for more than one (1) day.

(2) If the maximum breach inundation area and current damage evaluation predicts any of the following, the dam shall be classified as significant hazard:

(A) Interruption of service for not more than one (1) day on any of the following:

(i) A county road, state two-lane highway, or U.S. highway serving as the only access to a community.

(ii) A multilane divided state or U.S. highway, including an interstate highway.

(B) Interruption of service for not more than one (1) day on an operating railroad.

(C) Damage to any occupied quarters that would not render the structure unusable.

(D) Damage to important utilities where service would be interrupted for not more than one (1) day, but either of the following may occur:

(i) Buried lines can be exposed by erosion.

(ii) Towers, poles, and aboveground lines can be damaged by undermining or debris loading.

(3) If the maximum breach inundation area and current damage evaluation results predict none of the items in subdivision (1) or (2) and damage is limited to farm buildings, agricultural land, or local roads, the dam shall be classified as low hazard.

(Natural Resources Commission; 312 IAC 10.5-3-2; filed Jan 26, 2007, 10:45 a.m.: 20070221-IR-312060092FRA)

The complete text of the IAC section should be reviewed. Up to date regulation can be found at the following URL:

http://www.in.gov/dnr/water/

Appendix B
Emergency Action Plan Outline

This outline has been replaced.
Please refer to the:
"Indiana Dam Safety Inspection Manual"
Part 4 – Emergency Preparedness.

http://www.in.gov/dnr/water/

Also:
Refer to Appendix A –
"Emergency Action Plan templates"
located in Part 4 of the "Manual"

Appendix C
Geotechnical Addendum-Insitu/Field Testing

A. Geotechnical Addendum - Insitu/Field Testing

1. Field Permeability Tests

Field permeability tests are generally considered to be more representative of the hydraulic conductivity of foundation materials and existing embankment materials than are laboratory permeability tests. The field testing techniques may be the only practical means of establishing foundation permeability for certain material types.

Foundation Soil - The in-situ permeability of potential foundation materials may be determined by performing field permeability tests. Selected zones of the foundation profile including alluvial materials, which may be allowed to remain in place, residual foundation soils, and partially weathered rock, are conducive to this technique. The monitoring wells that may have been installed to better establish the ambient groundwater conditions typically can be used for the field permeability test. Bailing or slug tests are typical. Pumping tests or inflow tests may be appropriate where higher permeabilities exist. Monitoring wells should be carefully constructed to assure that the zone of material desired for testing has been isolated within the screened sections of the well by appropriate seals such as bentonite and grout. The field testing technique is generally considered to provide the horizontal permeability values directly, without the need for adjusting vertical laboratory permeability test results. In addition, a broader cross-section of the subsurface profile can be tested by this technique. Care should be exercised in higher permeability situations to assure that the values being measured do not represent the actual well materials involved in the well construction. These field techniques are typically only applicable to zones of material below existing groundwater levels. Therefore, laboratory-testing techniques are generally required for materials above the groundwater level so that saturation of the material can be established prior to testing.

Existing Embankment Fill Materials - Techniques utilized for the foundation soils can be considered for determining permeability values of existing dam embankment fill materials. This procedure is generally only applicable to the materials that exist below the currently established phreatic surface through the dam. Therefore, the existing reservoir would need to be impounded at the time of testing. This technique is generally not applicable where the lake has been temporarily drained.

Foundation Rock - Packer permeability tests are typically performed to determine the hydraulic conductivity of foundation rock. Either single or double packers are commonly employed to help isolate specific zones within the foundation rock profile. In most instances, fractures and discontinuities within the rock control the hydraulic conductivity of the material. However, the test results are commonly expressed as an equivalent permeability over the length of the test section. Relatively short test sections may be employed to help isolate higher permeability zones. As with the monitoring well type permeability tests, care should be exercised to assure that the hydraulic conductivity values being determined do not represent the hydraulic limitations of the packer test equipment.

2. Other Field Tests

Strength Testing - Various field testing techniques may be considered where soft or low consistency foundation materials exist that cannot be accurately modeled by Standard Penetration Testing or undisturbed sampling. The vane shear test is commonly employed in very soft cohesive deposits. Pressuremeter or dilatometer testing may be considered for a broad range of material types and consistencies. Cone penetrometer soundings may also be considered. To some extent, these field testing techniques have evolved as preferable in certain locations and certain geologic settings. These techniques normally would only be considered where direct support of a new embankment on very weak materials is being considered, or to supplement laboratory testing in materials that are difficult to sample.

Geophysical Methods - A variety of geophysical testing techniques are available and may be considered in certain applications. These approaches would typically be applicable to a very limited number of dam projects due to the specialized nature. The most common technique is the shallow seismic refraction survey, which can be useful in profiling difficult excavation materials. The seismic refraction survey would likely have most applicability in a dam study to generally screen potential borrow areas, since this technique can be negatively impacted by existing groundwater conditions. This typically provides a relatively low cost and expedient technique that generally does not require an invasive approach similar to test pits or borings.

Other Tests - Other field testing techniques may be considered for certain specialized applications. One possible test that would fit into this category would be tracer dye testing. This is used principally to determine the flow direction and rate of flow in karst geology.

B. Geotechnical Addendum - Instrumentation

1. Piezometric Levels

The monitoring of piezometric levels may be an important consideration for specific zones within the foundation of a dam during construction and fill placement, and to evaluate the development of the phreatic surface within the embankment during and subsequent to initial reservoir filling.

Locations - Piezometric levels may require monitoring within specific zones of embankment foundations, particularly where extensive low consistency fine grained materials exist or where there are concerns over the development of high pore pressures during embankment construction (end-of-construction stability). In such instances, the monitoring device will typically measure piezometric levels at specific locations. It is typically desirable to measure piezometric levels within the completed embankment as the reservoir fills and steady-state seepage conditions develop. Devices for this purpose typically require a broad vertical zone be monitored as the piezometric levels rise within the embankment. Piezometer locations in the foundation should be concentrated in the flood plain portion of the embankment footprint. Piezometric levels within the embankment will require devices placed at both edges of the crest, at or slightly beyond the downstream toe of the dam, and potentially within the downstream slope, particularly if berms are utilized on taller structures. These devices should be aligned to allow the phreatic surface development to be plotted. Multiple stations of such instrumentation may be needed on longer embankments.

Observation Wells - Observation wells and open (Casagrande) piezometers may be considered for many applications. These are typically well suited to monitoring the performance of foundations outside the embankment footprint during construction and within the embankment during initial reservoir filling. Short-screened sections are typically utilized for foundation monitoring. Longer screened sections can be utilized to monitor the unconfined phreatic surface within the embankment during initial filling. The observation wells are usually installed within the embankment after the fill is topped out.

Remote Reading Piezometers - These types of piezometers are well suited to monitoring foundation conditions during and subsequent to construction. Both pneumatic and electric vibrating wire type piezometers have been utilized for this purpose. They may be installed in the foundation of a dam prior to embankment construction, with tubing and wires placed in a manner that does not obstruct the subsequent construction. Remote readout locations outside the embankment footprint are typically utilized.

2. Settlement

The settlement performance of a dam and foundation is typically a consideration during and immediately following embankment construction. A typical scenario is a relatively thick compressible zone in the foundation of the proposed dam and settlement estimates performed during design indicate that significant settlements may occur.

Location - The settlement devices should target more compressible foundation zones, particularly in the vicinity of structures such as conduits. This would normally dictate a location within the flood plain area of the dam footprint. The settlement devices are often concentrated along the centerline; however, they may be placed in other areas.

Settlement Plates - Conventional settlement plates with riser pipes are the simplest forms of settlement monitoring device for the foundation. These are generally placed after foundation preparation is completed and immediately prior to commencement of embankment construction. Accurate elevations are obtained periodically during construction. These elevations should be referenced to the project datum. Additional readings are required immediately prior to and subsequent to adding additional sections of riser rod. These devices will create an obstruction to the earthmoving equipment during construction.

Remote Reading Settlement Transducers - Both pneumatic and electric vibrating wire settlement transducers may be considered. These are typically placed at strategic locations with the cables and tubing routed outside the embankment footprint to a stationary readout location. Such devices lessen the obstructions that exist during earthwork, but may not be as reliable.

Surface Monuments - Surface-monitoring points for settlement measurement should be installed immediately after topping out the embankment. These would be placed along the crest of the dam, and be adequately protected.

3. Seepage

The monitoring of seepage quantities during initial reservoir filling, and throughout the subsequent life of the structure, provides useful information on the performance of the dam. This monitoring is typically facilitated by measuring the outflows from the internal drainage system components.

Piped Outlets - Piped internal drainage system components are common. The outlet location should be protected through the use of headwalls, riprap, etc. The exposed portions of the piping system should be durable, and include animal guards. Pipes should also be placed to allow routine measurement of flow. This typically requires that the invert of the pipe be placed at least a foot above the local subgrade level.

Relief Wells - Relief wells into the foundation are utilized on certain projects, particularly for gravity dams. These should be placed to allow for easy monitoring of the outflows and such that they are protected from damage.

Weirs - Seepage monitoring weirs may be considered in applications where seepage outflows exit from non-point sources, such as rock toe drains. The collected seepage should be routed into a small pool upstream of the weir, and sufficient fall should be provided to allow the V-notch weir to perform as intended. Staff gauges are typically required to determine the level of the water in the pool upstream of the weir in conjunction with seepage quantity calculations.

4. Other Instrumentation

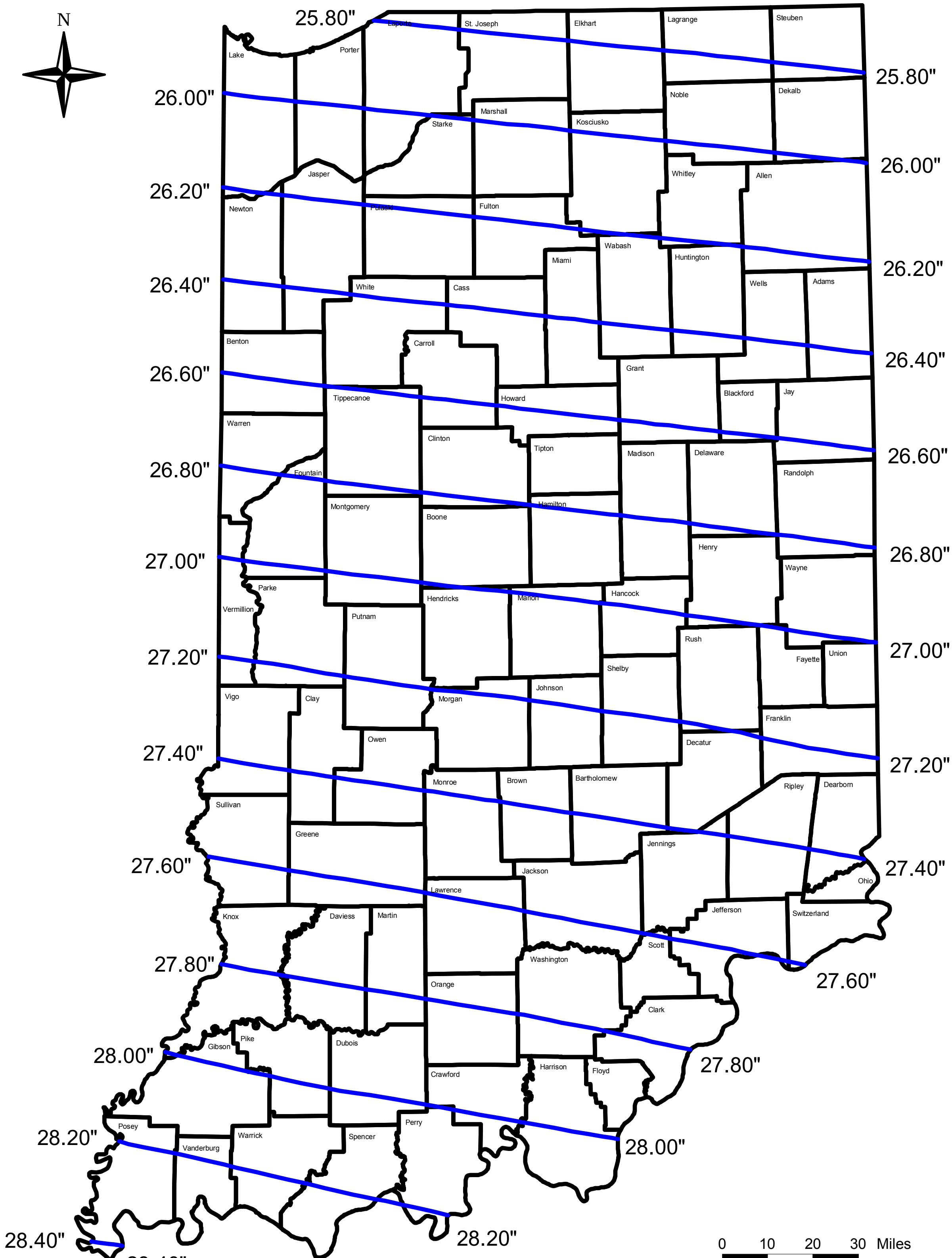
Additional types of instrumentation may be considered in certain special applications. The engineer should determine if specific project requirements dictate the need for specialized instrumentation.

Inclinometers - These devices may be installed in situations where measurement of horizontal movements is required. A fairly common application would be on an existing dam where concerns exist over slope instability.

Crack Monitoring - Crack-monitoring devices may be needed on appurtenant structures, or to evaluate movements across discontinuities of concrete gravity dam sections.

Appendix D
Rainfall Distribution &
Probable Maximum Precipitation

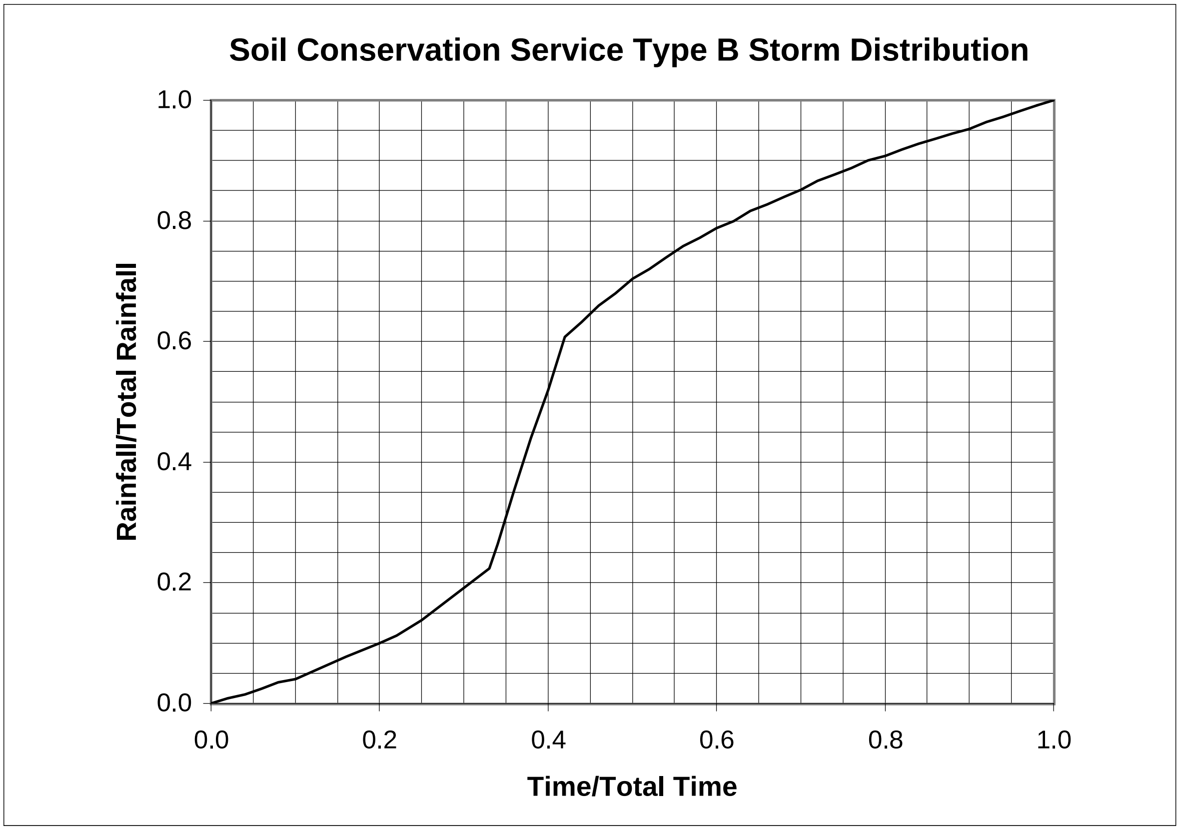
ALL SEASON 6 HOUR PMP FOR 10 SQUARE MILES



REFERENCE
HYDROMETEORLOGICAL
REPORT NO.51
NATIONAL WEATHER SERVICE

STATE OF INDIANA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WATER

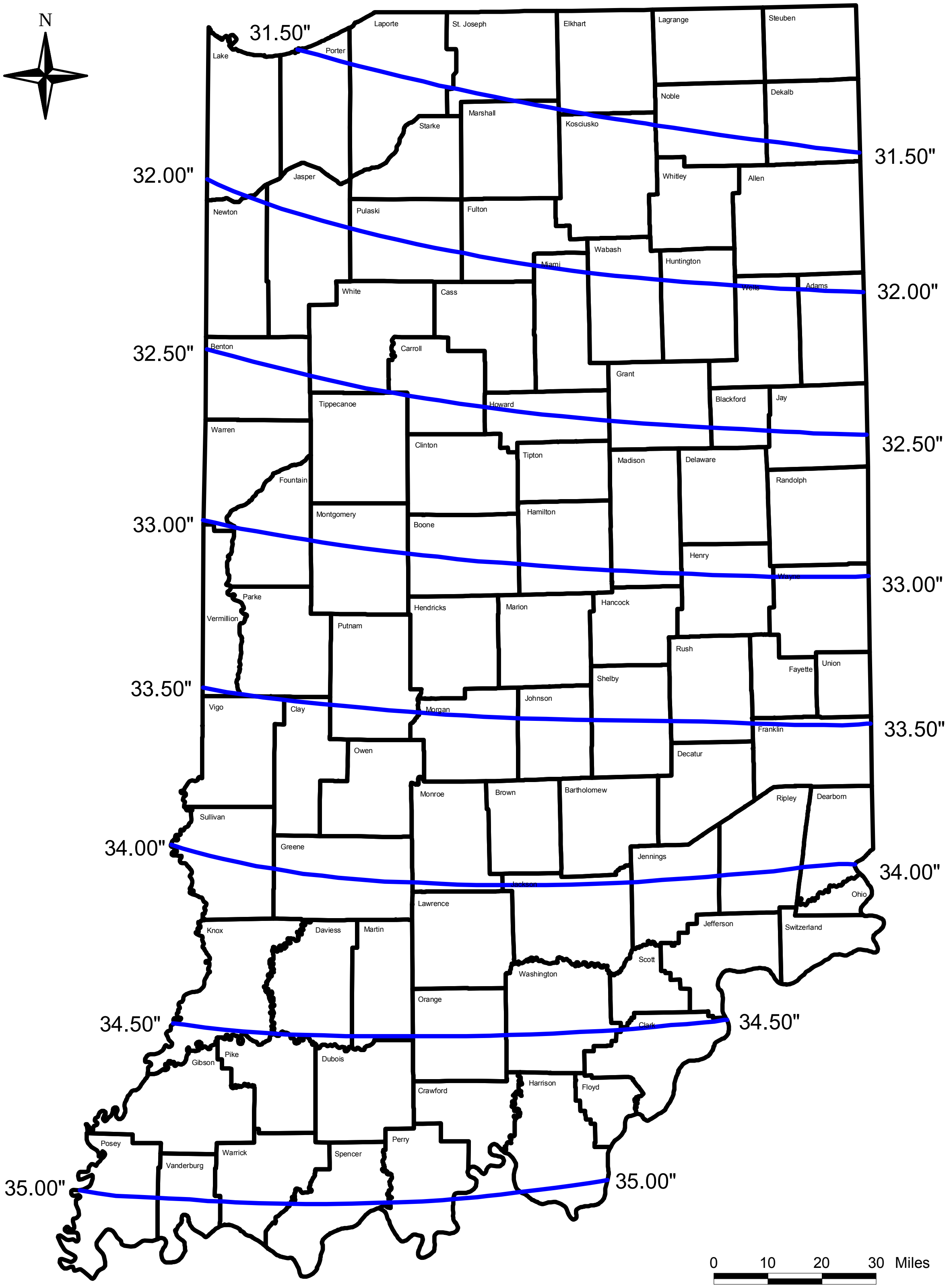
INDIANA DEPARTMENT OF NATURAL RESOURCES



Time/Total Time	Rainfall/Total Rainfall	Time/Total Time	Rainfall/Total Rainfall
0.000	0.000	0.580	0.772
0.020	0.008	0.600	0.788
0.040	0.015	0.620	0.800
0.060	0.024	0.640	0.817
0.080	0.035	0.660	0.827
0.100	0.040	0.680	0.840
0.160	0.077	0.700	0.852
0.200	0.100	0.720	0.866
0.220	0.112	0.740	0.877
0.250	0.138	0.760	0.888
0.330	0.224	0.780	0.900
0.340	0.264	0.800	0.908
0.360	0.354	0.820	0.918
0.380	0.440	0.840	0.928
0.400	0.520	0.860	0.936
0.420	0.608	0.880	0.945
0.440	0.632	0.900	0.952
0.460	0.660	0.920	0.964
0.480	0.680	0.940	0.972
0.500	0.704	0.960	0.982
0.520	0.720	0.980	0.992
0.540	0.739	1.000	1.000
0.560	0.758		

Figure 1. NRCS Type B Rainfall Distribution

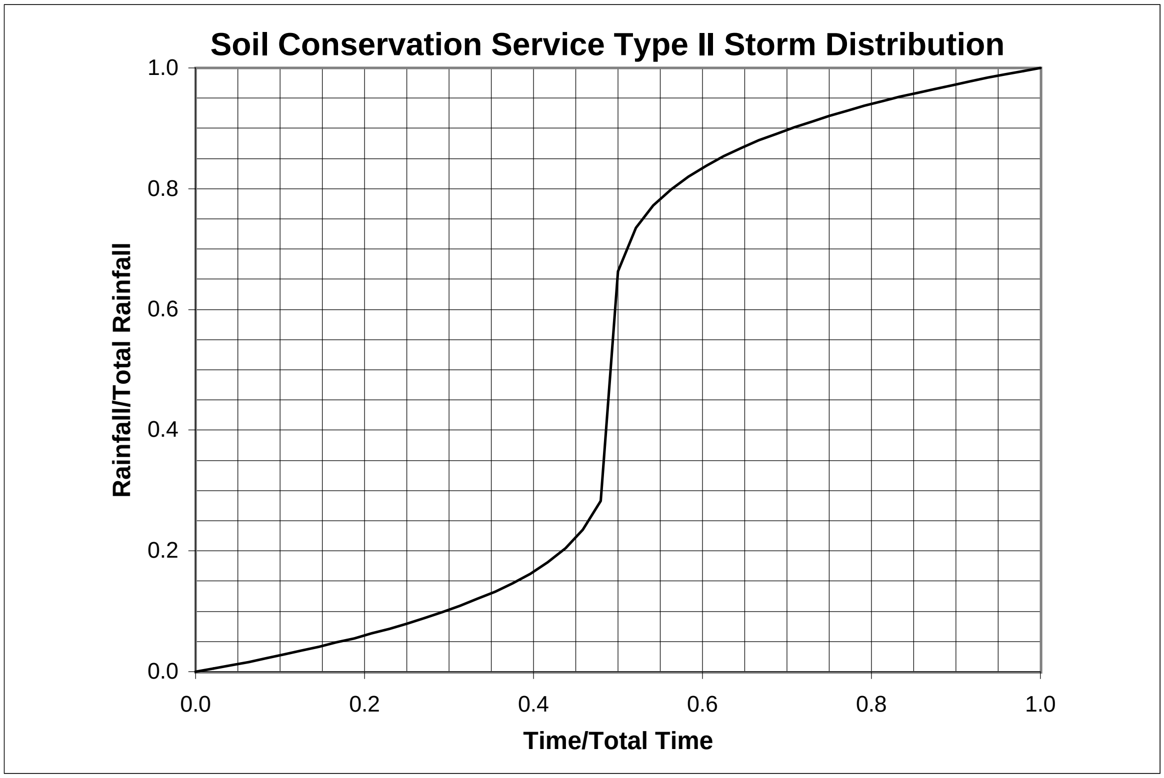
ALL SEASON 24 HOUR PMP FOR 10 SQUARE MILES



REFERENCE
HYDROMETEORLOGICAL
REPORT NO.51
NATIONAL WEATHER SERVICE

STATE OF INDIANA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WATER

INDIANA DEPARTMENT OF NATURAL RESOURCES

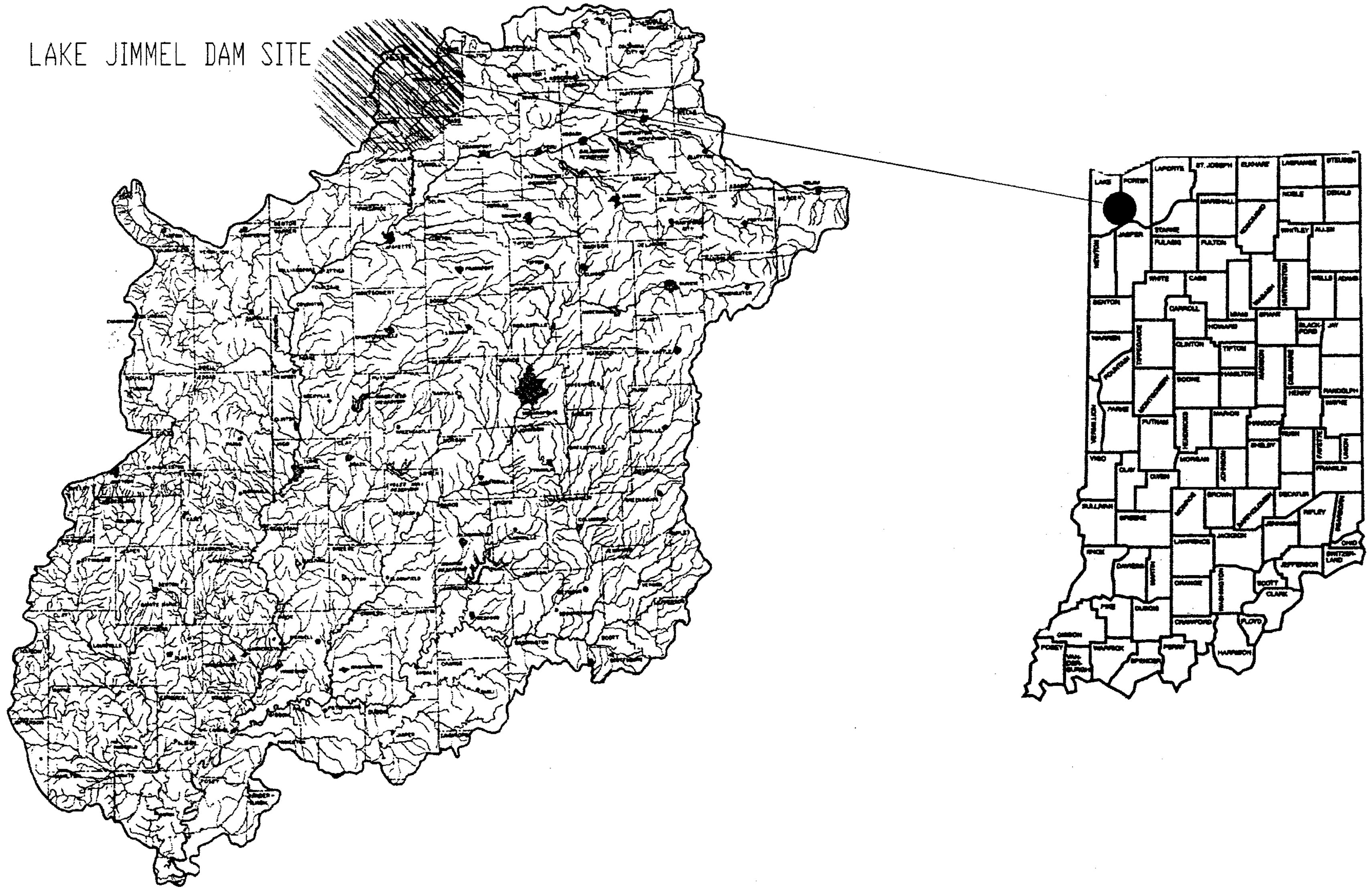


Time/Total Time	Rainfall/Total Rainfall	Time/Total Time	Rainfall/Total Rainfall
0.000	0.0000	0.521	0.7351
0.021	0.0053	0.542	0.7724
0.042	0.0108	0.563	0.7989
0.063	0.0164	0.583	0.8197
0.083	0.0223	0.604	0.8380
0.104	0.0284	0.625	0.8538
0.125	0.0347	0.646	0.8676
0.146	0.0414	0.667	0.8801
0.167	0.0483	0.688	0.8914
0.188	0.0555	0.708	0.9019
0.208	0.0632	0.729	0.9115
0.229	0.0712	0.750	0.9206
0.250	0.0797	0.771	0.9291
0.271	0.0887	0.792	0.9371
0.292	0.0984	0.813	0.9446
0.313	0.1089	0.833	0.9519
0.333	0.1203	0.854	0.9588
0.354	0.1328	0.875	0.9653
0.375	0.1467	0.896	0.9717
0.396	0.1625	0.917	0.9777
0.417	0.1808	0.938	0.9836
0.438	0.2042	0.958	0.9892
0.458	0.2351	0.979	0.9947
0.479	0.2833	1.000	1.0000
0.500	0.6632		

Figure 2. NRCS Type II Rainfall Distribution

Appendix E
Selected Plan Sheets for Illustration Purposes

CONSTRUCTION PLANS
LAKE JIMMEL DAM



SUPERB ENGINEERING, INC.
444 WATERSHED DRIVE
OUTLET, INDIANA

INDEX OF DRAWINGS

NOTE: OTHER SHEETS MAY BE NECESSARY TO PROVIDE DETAILS FOR THE PRINCIPAL SPILLWAY INLET STRUCTURE, OUTLET STRUCTURE, AND ANTI-SEEP COLLARS.

THE APPROVAL SIGNATURES APPEARING IN THE TITLE BLOCK ON THIS SHEET CONSTITUTE APPROVAL OF ALL DRAWINGS LISTED IN THE INDEX

PREPARED BY: ______________________

REVIEWED BY: ______________________

QUALITY ASSURANCE: ______________________

PROJECT ENGINEER: ______________________

APPROVED BY: ______________________

DATE: ______________________

REVISIONS		
DESCRIPTION	DATE	APPROVED

ENGINEER'S SIGNATURE
DATE, AND SEAL

NOTE: THIS IS A SAMPLE SET OF PLANS-NOT FOR CONSTRUCTION

LEGEND

- County Line
- Township Line
- Section Line
- Property Line
- Base Line
- Centerline of Improvements
- Watershed Boundary
- Sub-Watershed Boundary
- Approximate Limit of Work Area
- Paved Road
- Improved Road
- Private or Field Road
- Bridge
- Railroad
- Fence, Existing
- Fence, to be Removed
- Fence, to be Constructed
- Power Line (location of pole)
- High Voltage Transmission Line (location of pole) — Poles
- Pipe Line or Buried Cable
- Diversion
- Stream, Flow line
- Woodland Boundary
- Building
- Section Corner — 615/718
- Section Center — 5
- Bench Mark, Permanent — x B.M.
- Bench Mark, Temporary — x T.B.M.
- Contours — 570
- Foundation Trench Drain — PIPE
- Clearing and/or Grubbing Boundary — C — C
- Right of Way Boundary

GENERAL NOTES

North Arrow is Magnetic North
Elevations of pipes refer to invert elevations
Cross sections shown as looking downstream
Chamfer all exposed concrete edges 3/4"

DEFINITION OF TERMS

S-Grade of channel in feet of drop per foot of length
b-Bottom width of channel in feet
SS-Side Slope, horizontal to vertical
T-Top width of dike, levee or fill in feet
FH-Fill height of dike in feet (vertical distance from bottom of channel to top of dike)
NTS-Not to Scale

EARTHWORK SYMBOLS

Class of fill .... A B C
Excavation-Common .... EC
Excavation-Rock .... ER
Channel Excavation-Common .... CEC

GEOLOGIC INFORMATION LEGEND

Unified classification by Visual-Manual Procedure in the field (ASTM D-2488), except where indicated by *.
Unified classification based on laboratory analysis of selected samples (ASTM D 2487)

UNIFIED SOIL CLASSIFICATION SYSTEM SYMBOLS

COARSE-GRAINED SOILS

GW-Well graded gravels, gravel-sand mixtures little or no fines
GP-Poorly graded gravels, gravel-sand mixtures, little or no fines.
GM-Silty gravels, gravel-sand-silt mixtures
GC-Clayey gravels, gravel-sand-clay mixtures.
SW-Well graded sands, gravelly sands, little or no fines
SP-Poorly graded sands, gravelly sands, little or no fines
SM-Silty sands, sand-silt mixtures
SC-Clayey sands, sand-caly mixtures

FINE-GRAINED SOILS

ML-Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity
CL-Inorganic clays of low to medium plasticity, gravelly, sandy, silty or lean clays
OL-Organic silts and silty clays of low plasticity.
MH-Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
CH-Inorganic clays of high plasticity, fat clays.
OH-Organic clays of medium to high plasticity, organic silts.
PT-Peat and other highly organic soils.

CONSOLIDATED MATERIAL

Cng-Conglomerate	Ls-Limestone
Ss-Sandstone	Dol-Dolomite
Sh-Shale	Co-Coal
Sist-Siltstone	Gyp-Gypsum
Ma-Marl	Cht-Chert

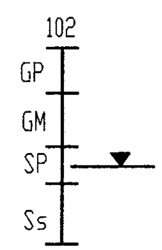
OTHER SYMBOLS

- Drill hole logged only
- Drill hole samples
- Dip and Strike
- Pit or trench logged only
- Pit or trench samples
- Ground water level

TEST HOLE NUMBERING SYSTEM

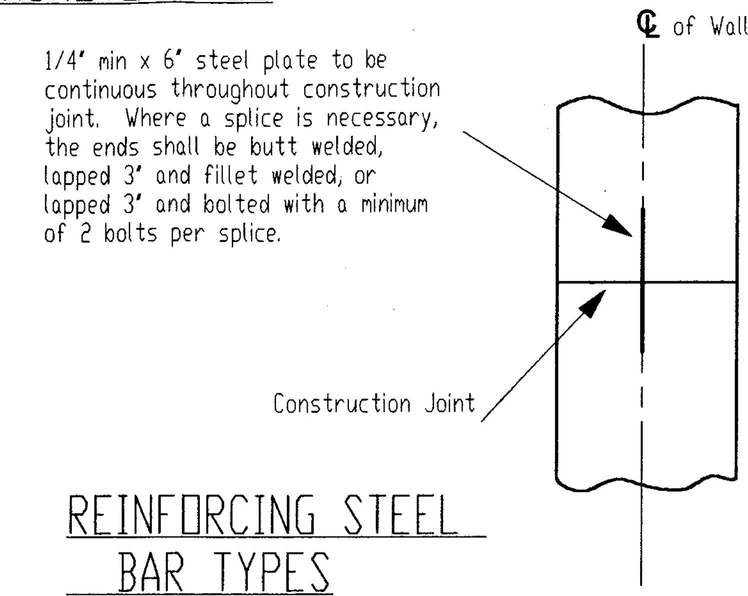
Centerline of Dam	1-99
Borrow area	101-199
Emergency Spillway	201-299
Centerline of outlet structure	301-399
Stream Channel	401-499
Drain Line	501-599
Correlation holes	601-699
Other	701-799

SAMPLE PLOT

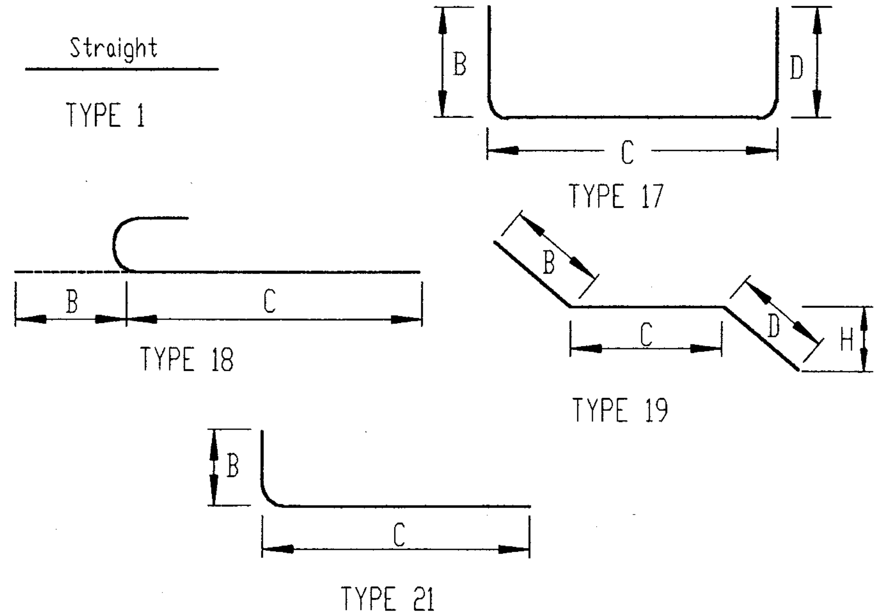


Notes:
1. Geologic investigation made in July, 2000 by Hardrock Exploration, Inc.
2. Ground water levels are as noted at the time of the investigation.
3. Records of the site investigation and geotechnical testing report may be reviewed by prospective bidders by contacting the office issuing the invitation.

DETAIL OF CONSTRUCTION JOINT FOR CONCRETE WALL



REINFORCING STEEL BAR TYPES

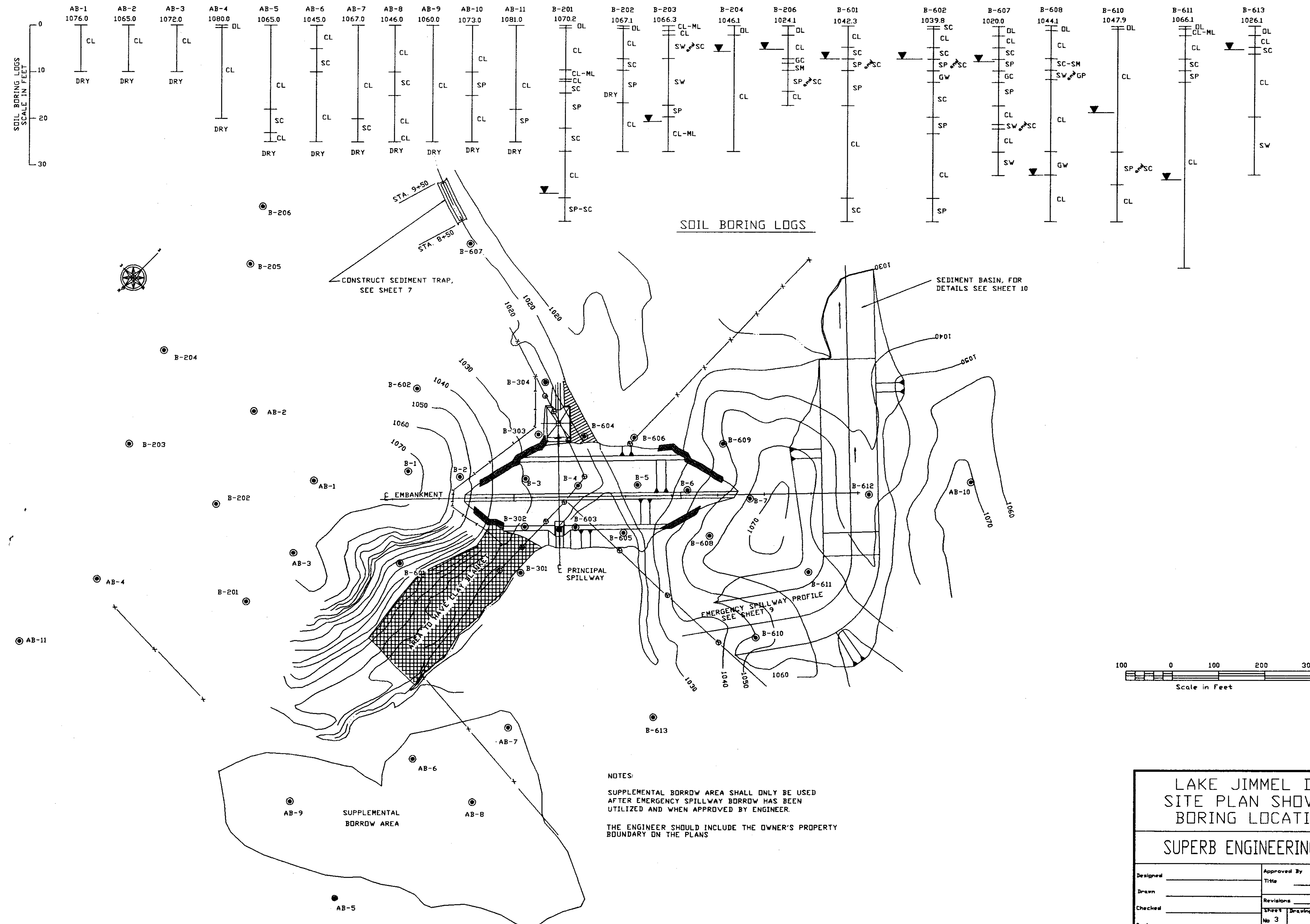


Notes:
1. Steel bending shall meet requirements in ACI Standard 315
2. Steel will be 2" from either inside or soutside face respectively.
3. Steel will be 3" from bottom of apron.

LAKE JIMMEL DAM
LEGEND AND INFORMATION

SUPERB ENGINEERING, INC

Designed		Approved By	
Drawn		Title	
Checked		Revisions	
Scale		Sheet No 2 of 15	Drawing No.



NOTES:

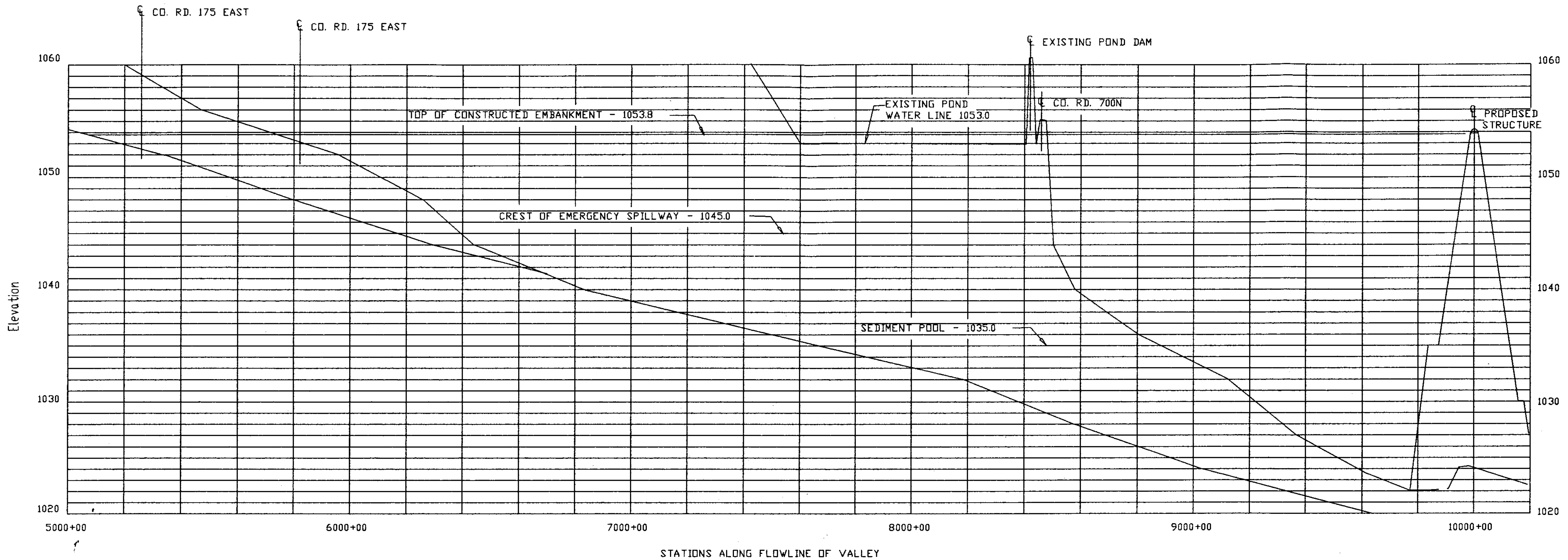
SUPPLEMENTAL BORROW AREA SHALL ONLY BE USED AFTER EMERGENCY SPILLWAY BORROW HAS BEEN UTILIZED AND WHEN APPROVED BY ENGINEER.

THE ENGINEER SHOULD INCLUDE THE OWNER'S PROPERTY BOUNDARY ON THE PLANS

LAKE JIMMEL DAM SITE PLAN SHOWING BORING LOCATIONS

SUPERB ENGINEERING, INC

Designed	Approved By
Drawn	Title
Checked	Revisions
Scale	Sheet No 3 of 15 / Drawing No.

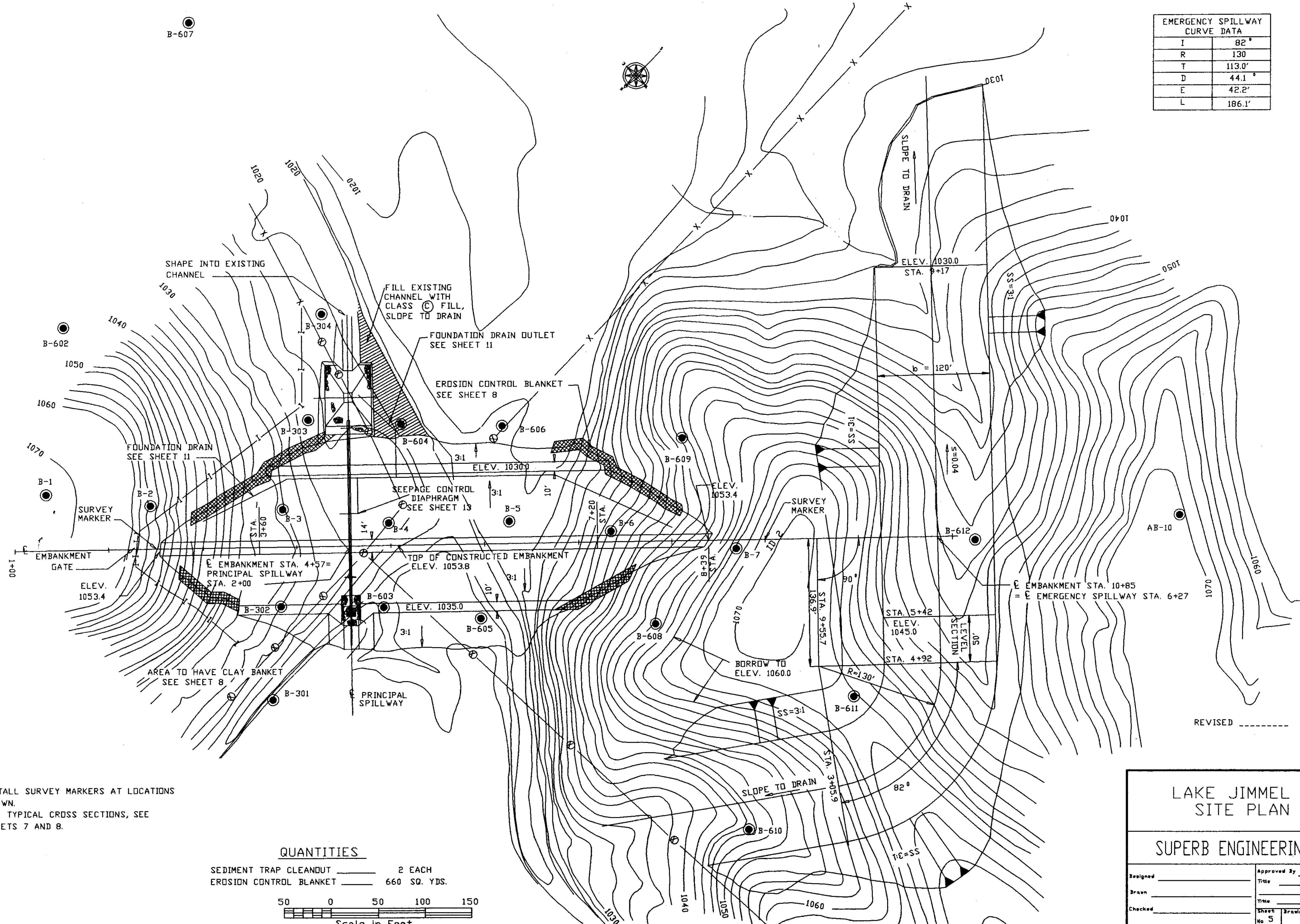


PROFILE ALONG CENTERLINE OF VALLEY

NOTE: UPSTREAM OBSTRUCTIONS SHOULD BE CONSIDERED IN THE DESIGN OF THE DAM AND RESERVOIR.
OBSTRUCTIONS MAY INCLUDE BRIDGES, CULVERTS, DAMS, BUILDINGS, AND ADJACENT PROPERTY

LAKE JIMMEL DAM VALLEY PROFILE	
SUPERB ENGINEERING, INC	
Designed	Approved By
Drawn	Title
Checked	Revision
Scale	Sheet No. 4 of 15 Drawing No.

EMERGENCY SPILLWAY CURVE DATA	
I	82°
R	130
T	113.0'
D	44.1°
E	42.2'
L	186.1'



REVISED _________

NOTES:
1- INSTALL SURVEY MARKERS AT LOCATIONS SHOWN.
2- FOR TYPICAL CROSS SECTIONS, SEE SHEETS 7 AND 8.

QUANTITIES

SEDIMENT TRAP CLEANOUT ______ 2 EACH
EROSION CONTROL BLANKET ______ 660 SQ. YDS.

50 0 50 100 150
Scale in Feet

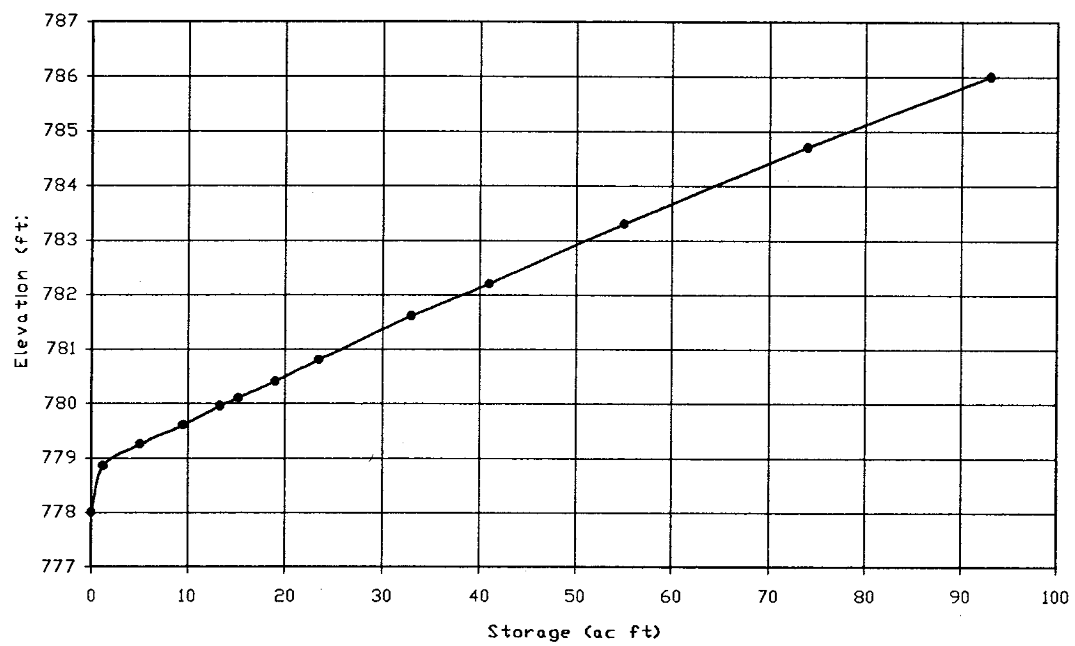
LAKE JIMMEL DAM SITE PLAN

SUPERB ENGINEERING, INC

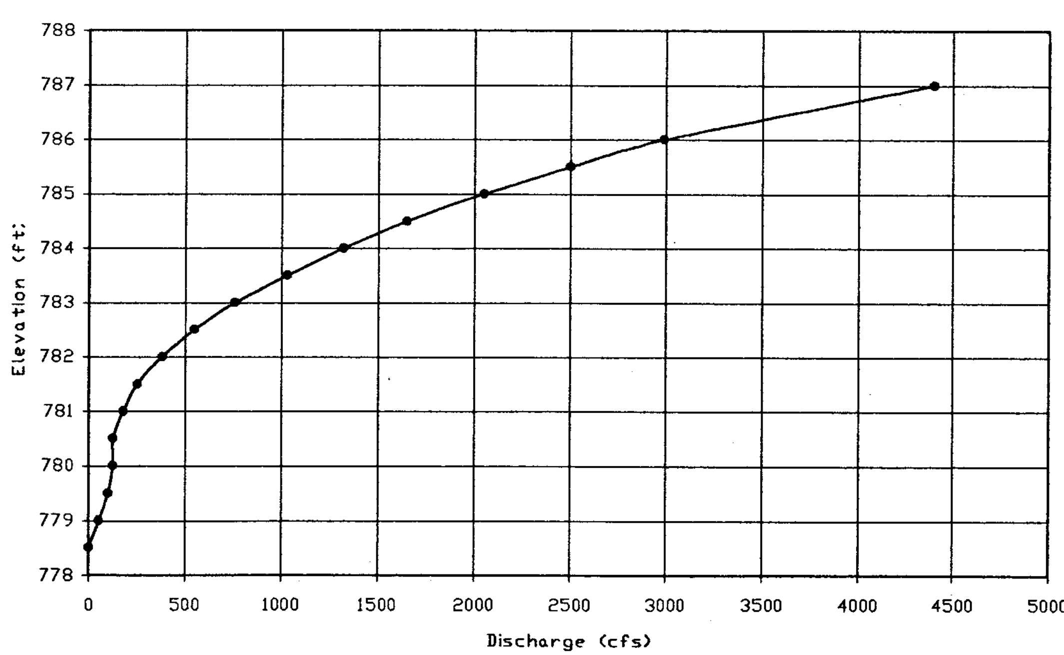
Designed ________ Approved By ________
Drawn ________ Title ________
Checked ________ Title ________
Scale ________ Sheet No 5 of 15 Drawing No.

HYDRAULIC DATA AND CURVES

LAKE JIMMEL DAM STAGE-STORAGE



LAKE JIMMEL DAM RATING CURVE



PHYSICAL DATA

Hazard Classification ____________________
Drainage Area (sq mi) ____________________
Time of Concentration, Tc (hrs) __________
Runoff Curve Number ____________________
(AMC II Conditions) ____________________

STRUCTURAL DATA

Principal Spillway
- Material ____________________
- Length ____________________
- Size ____________________
- Height ____________________
- Width ____________________
- Crest Elev/Area ____________________
- Weir Length ____________________

Emergency Spillway
- Material ____________________
- Base Width ____________________
- Side Slope ____________________
- Crest Elev/Area/Stor ______________
- Shape ____________________
- 'n' value ____________________
- Length/Slope of Spillway __________
- Armoring ____________________

Top of Dam
- Elev ____________________
- Area ____________________
- Storage ____________________
- Freeboard ____________________
- Length of Dam ____________________
- Channel Outlet Elev ______________

HYDROLOGIC/HYDRAULIC DATA

DESCRIPTION (UNITS)	VALUE
BASIN HYDROLOGY	
Rainfall (in)	
Duration (hrs)	
%PMP or -yr Frequency	
Runoff (in)	
Runoff (acre ft)	
Peak inflow (cfs)	
PRINCIPAL SPILLWAY	
Max. Discharge (cfs)	
Max velocity-at Opening (fps)	
Max velocity-exit channel (fps)	
BREACH ANALYSIS	
Shape of Breach	
Width (ft)	
Sideslope	
Time to Failure (hrs)	
Immediate Downstream Elev (ft)	

LAKE JIMMEL DAM
HYDRAULIC DATA
AND CURVES

SUPERB ENGINEERING, INC

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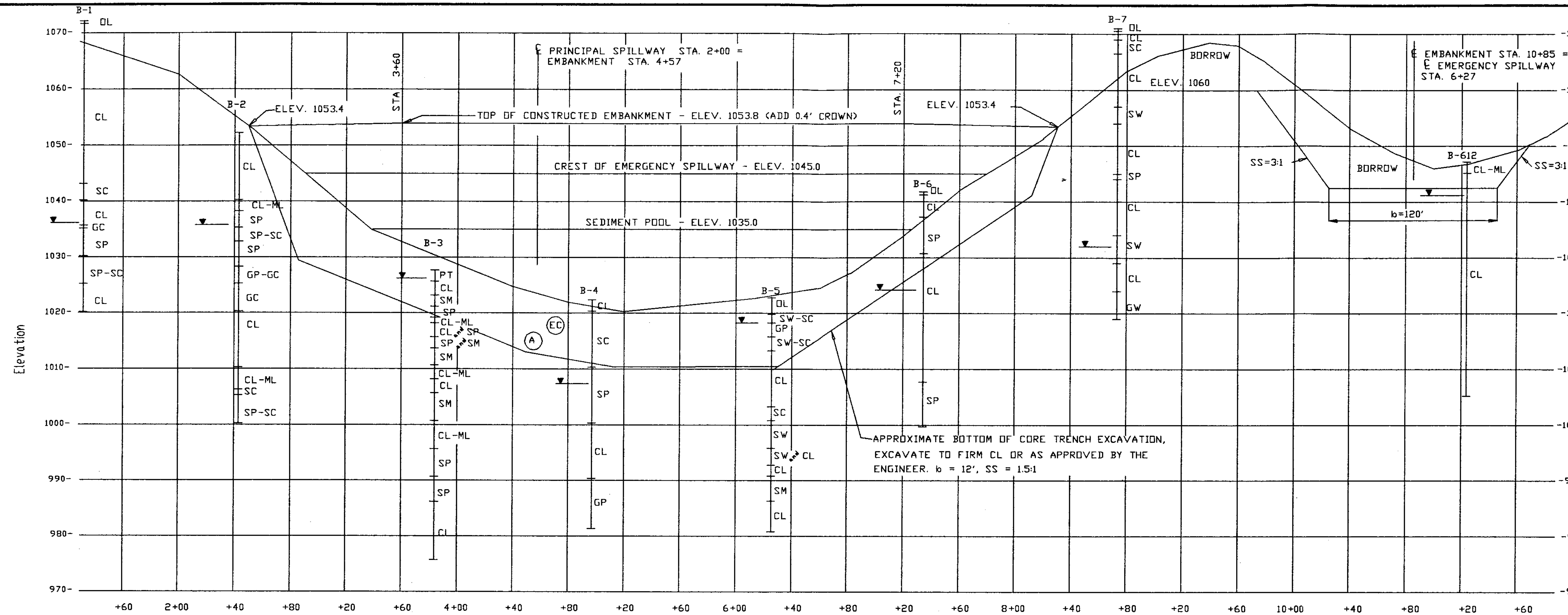
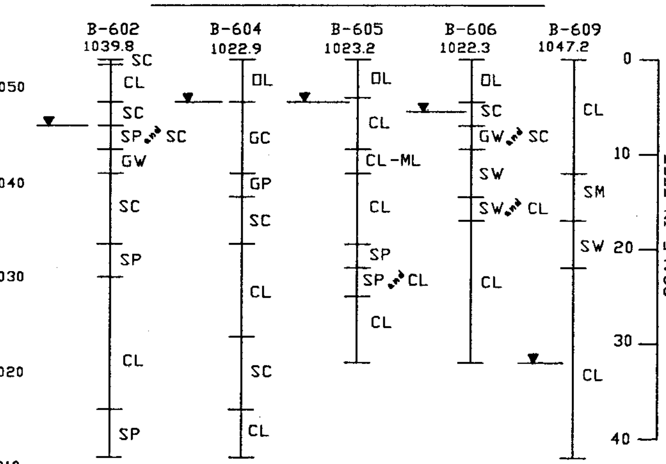
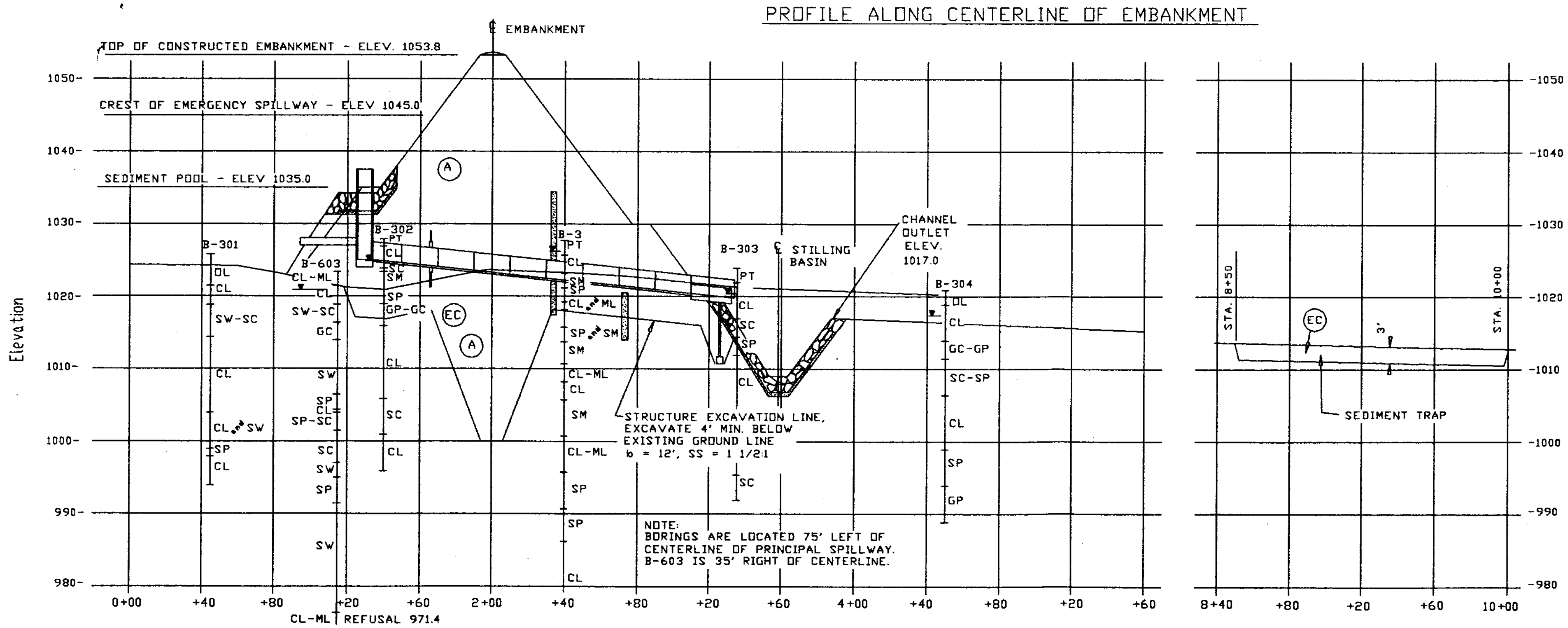
Checked		Revision	
Scale		Sheet No 6 of 15	Drawing No.



PROFILE ALONG CENTERLINE OF EMBANKMENT

ADDITIONAL SOIL BORINGS





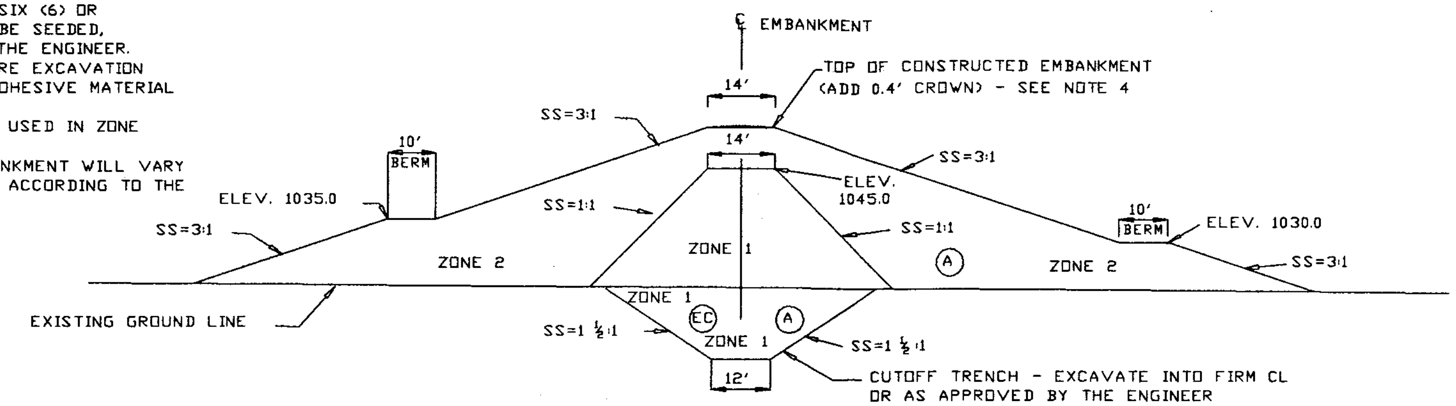
PROFILE ALONG CENTERLINE OF PRINCIPAL SPILLWAY

LAKE JIMMEL DAM
PROFILES AND
SOIL BORING LOGS

SUPERB ENGINEERING, INC

Designed		Approved By	
Drawn		Title	
Checked		Revision	
Scale		Sheet No. 7 of 15	Drawing No.

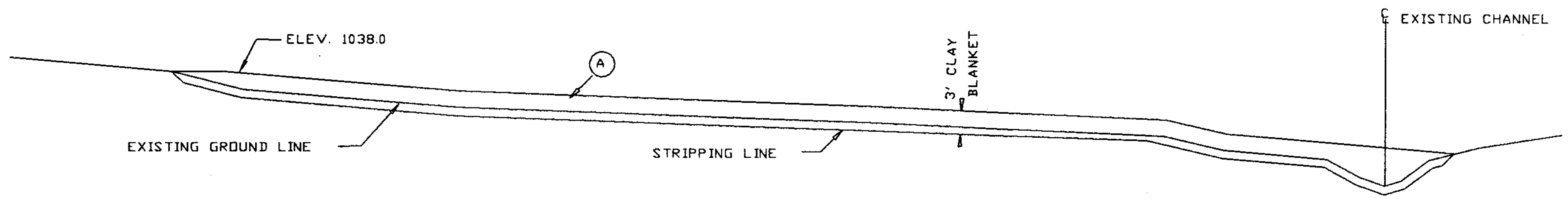
NOTES:
1 - TOPSOIL SHALL BE PLACED IN THE OUTSIDE SIX (6) OR MORE INCHES OF THE EMBANKMENT AREA TO BE SEEDED, IN HORIZONTAL LIFTS, WHERE DIRECTED BY THE ENGINEER.
2 - BACKFILL FOR CUTOFF TRENCH AND STRUCTURE EXCAVATION SHALL CONSIST OF THE MOST IMPERVIOUS, COHESIVE MATERIAL AVAILABLE.
3 - NON-PLASTIC SP & SW MATERIALS SHALL BE USED IN ZONE 2 AREAS.
4 - ELEVATIONS FOR TOP OF CONSTRUCTED EMBANKMENT WILL VARY ALONG THE CENTERLINE OF THE EMBANKMENT ACCORDING TO THE PROFILE SHOWN ON SHEET 7.



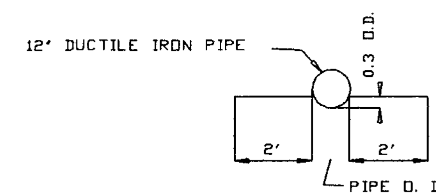
SECTION ON CENTERLINE

TYPICAL FILL MATERIAL MOISTURE DENSITY RELATIONSHIP						
SOURCE OF MATERIAL				LABORATORY TEST INFORMATION		PLACEMENT REQUIREMENT
LOCATION BORING NUMBER	APPROXIMATE DEPTH(FT.) FROM	TO	UNIFIED SOIL CLASSIFICATION	DRY DENSITY (MAXIMUM)	MOISTURE % (OPTIMUM)	EMBANKMENT SECTION
AB-10A	0	10	CL	130.2	10.6	ALL
AB-10B	15	25	CL	133.8	7.8	ALL
AB-5	0	18	CL	121.4	13.9	ALL
AB-8	10	15	SP	140.3	5.8	2
B-611	10	12	SP	*	*	2

* NON PLASTIC SP & SW MATERIALS SHALL BE COMPACTED TO A DRY DENSITY OF 125 LBS./CU. FT. MINIMUM.



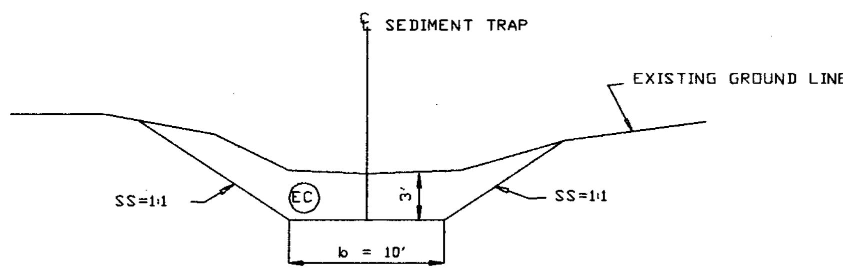
TYPICAL CROSS SECTION OF CLAY BLANKET AREA



TYPICAL CROSS SECTION OF DUCTILE IRON PIPE PLACEMENT

RIPRAP GRADATION

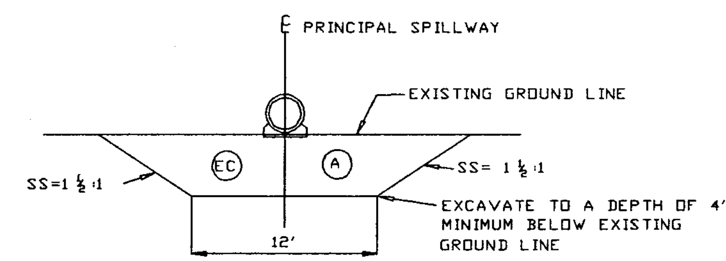
AT LEAST 50% BY WEIGHT SHALL CONSIST OF PIECES LARGER THAN 12 INCHES. THE MAXIMUM SIZE SHALL BE 18 INCHES AND NOT MORE THAN 15% OF THE PIECES BY WEIGHT SHALL BE LESS THAN 4 INCHES.



TYPICAL CROSS SECTION OF SEDIMENT TRAP

RIPRAP BEDDING GRADATION

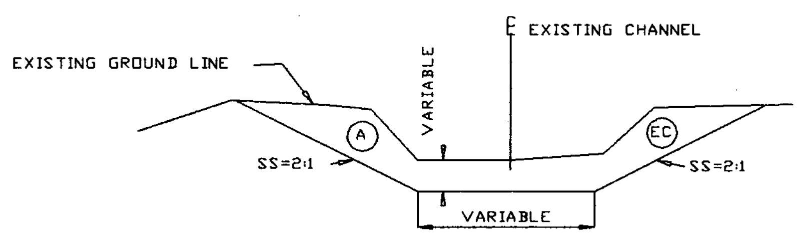
RIPRAP BEDDING SHALL BE INDIANA STATE HIGHWAY COARSE AGGREGATE SIZE NO. 5 OR EQUIVALENT.



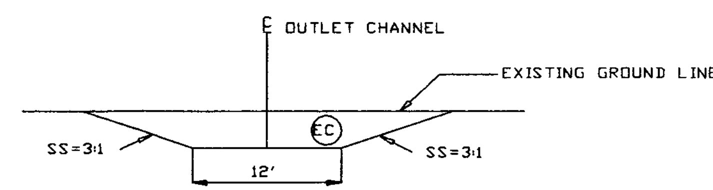
TYPICAL CROSS SECTION OF STRUCTURE EXCAVATION

QUANTITIES

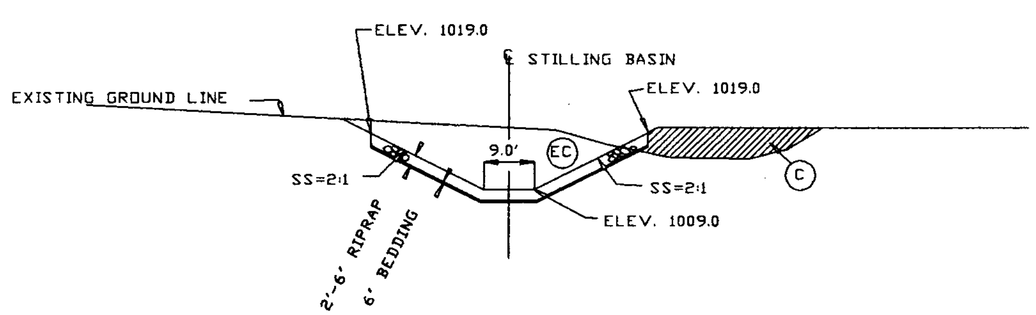
EXCAVATION - COMMON:		
CUTOFF TRENCH	4,370	CU. YDS.
STRUCTURE EXCAVATION	380	CU. YDS.
STREAM CHANNEL CLEANOUT	590	CU. YDS.
OUTLET CHANNEL AND SEDIMENT TRAP	150	CU. YDS.
STILLING BASIN	2,007	CU. YDS.
TOTAL	7,497	CU. YDS.
EARTH FILL - CLASS A:		CU. YDS.
EMBANKMENT	52,250	CU. YDS.
CLAY BLANKET	5,550	CU. YDS.
CUTOFF TRENCH BACKFILL	4,370	CU. YDS.
STRUCTURE EXCAVATION BACKFILL	380	CU. YDS.
STREAM CHANNEL BACKFILL	590	CU. YDS.
TOTAL	63,140	CU. YDS.
RIPRAP	643	TONS
RIPRAP BEDDING	114	CU. YDS.



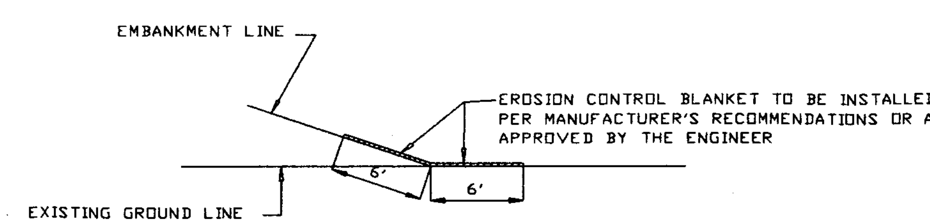
TYPICAL CROSS SECTION OF STREAM CHANNEL CLEANOUT



TYPICAL CROSS SECTION OF OUTLET CHANNEL



TYPICAL CROSS SECTION OF STILLING BASIN

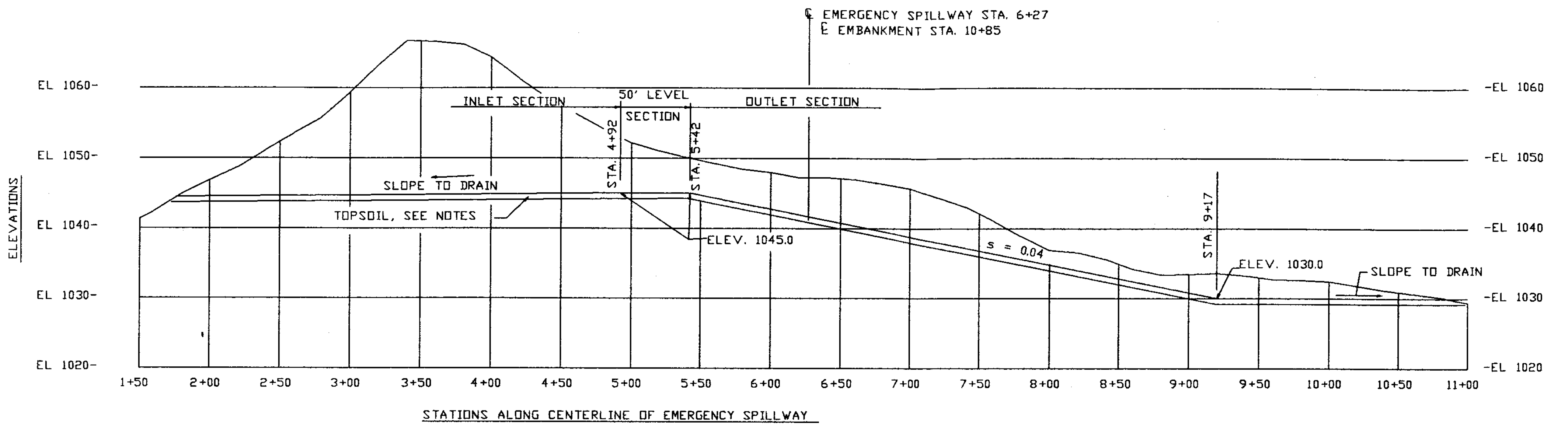


TYPICAL CROSS SECTION OF EROSION CONTROL BLANKET PLACEMENT

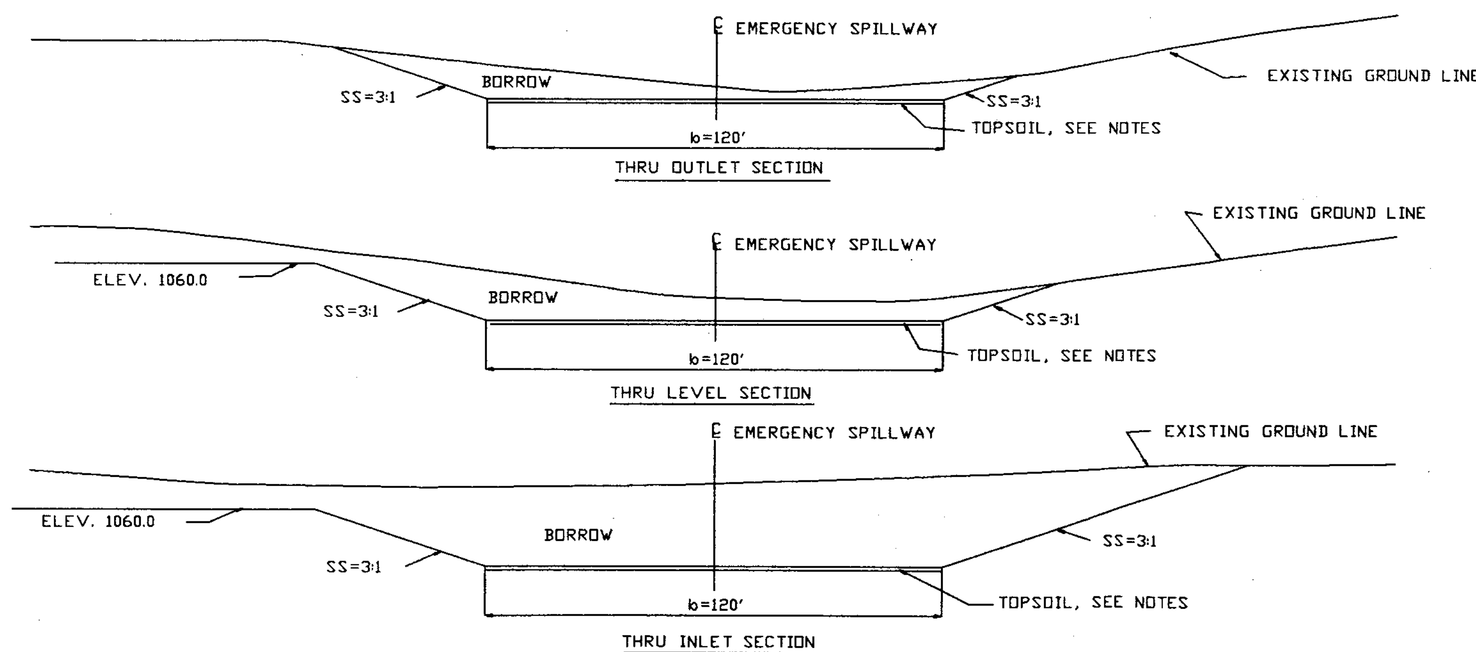
LAKE JIMMEL DAM
TYPICAL CROSS SECTIONS

SUPERB ENGINEERING, INC

Designed		Approved By	
Drawn		Title	
Checked		Revised	
Scale	NOT TO SCALE	Sheet No. 8 of 15	Drawing No.



PROFILE ALONG CENTERLINE OF EMERGENCY SPILLWAY



TYPICAL CROSS SECTIONS

NOT TO SCALE

NOTES:

1- PLACE TOPSOIL IN EMERGENCY SPILLWAY BOTTOM, 1 FOOT MIN THICKNESS. AREAS WHERE SP AND SW MATERIALS ARE ENCOUNTERED WILL BE EXCAVATED TO A DEPTH OF 2 FEET AND BACKFILLED WITH COMPACTED FILL MATERIAL.

2- THE REMAINING AVAILABLE TOPSOIL SHALL BE SPREAD ON THE EMERGENCY SPILLWAY, WHERE DIRECTED BY THE ENGINEER.

QUANTITIES

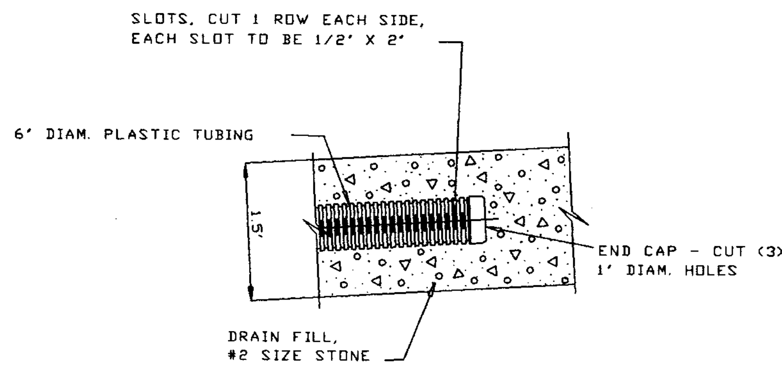
BORROW - EMERGENCY SPILLWAY ______________ 48,475 CU. YDS.

TOPSOIL SPREADING - EMERGENCY SPILLWAY ______ 11,920 SQ. YDS

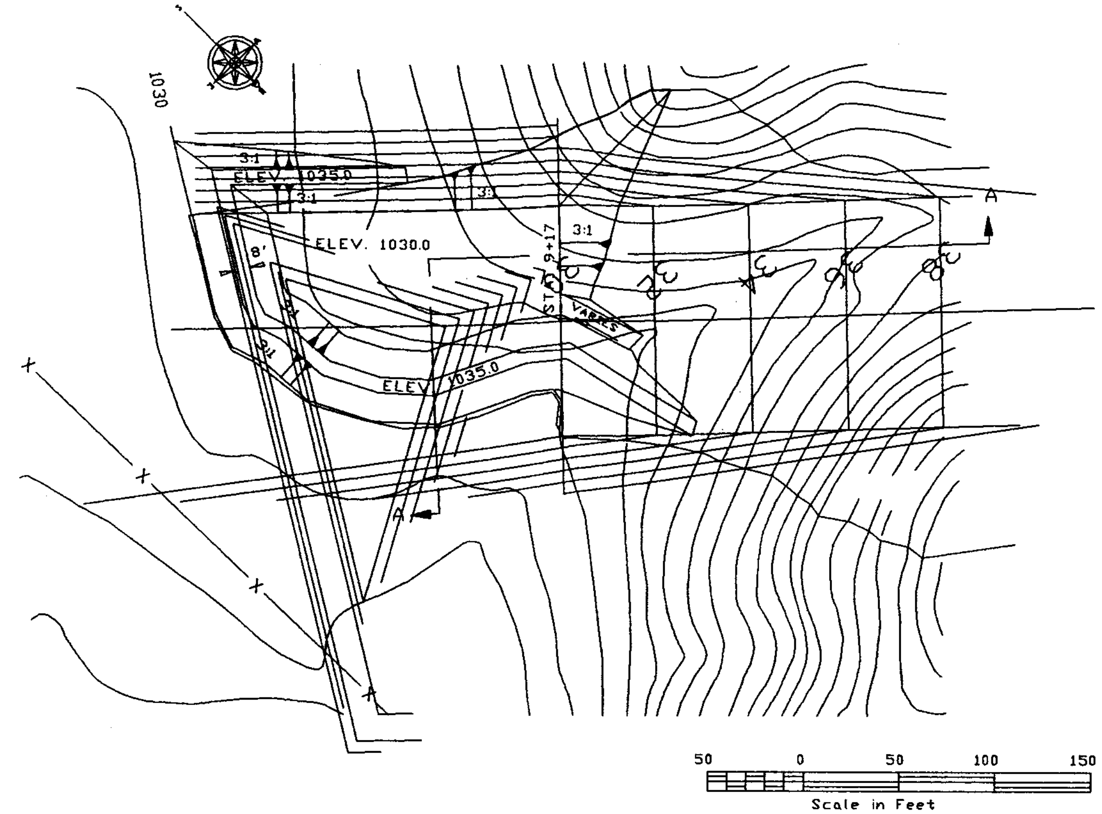
LAKE JIMMEL DAM EMERGENCY SPILLWAY DETAILS

SUPERB ENGINEERING, INC

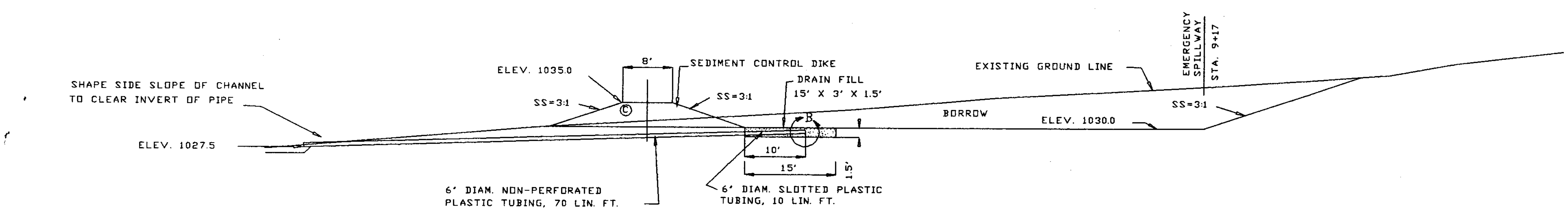
Designed	Approved By
	Title
Drawn	
	Revision
Checked	Sheet No 9 of 15 / Drawing No.
Scale	



DETAIL 'B'
NOT TO SCALE



SEDIMENT BASIN LOCATION



SECTION A-A
NOT TO SCALE

QUANTITIES

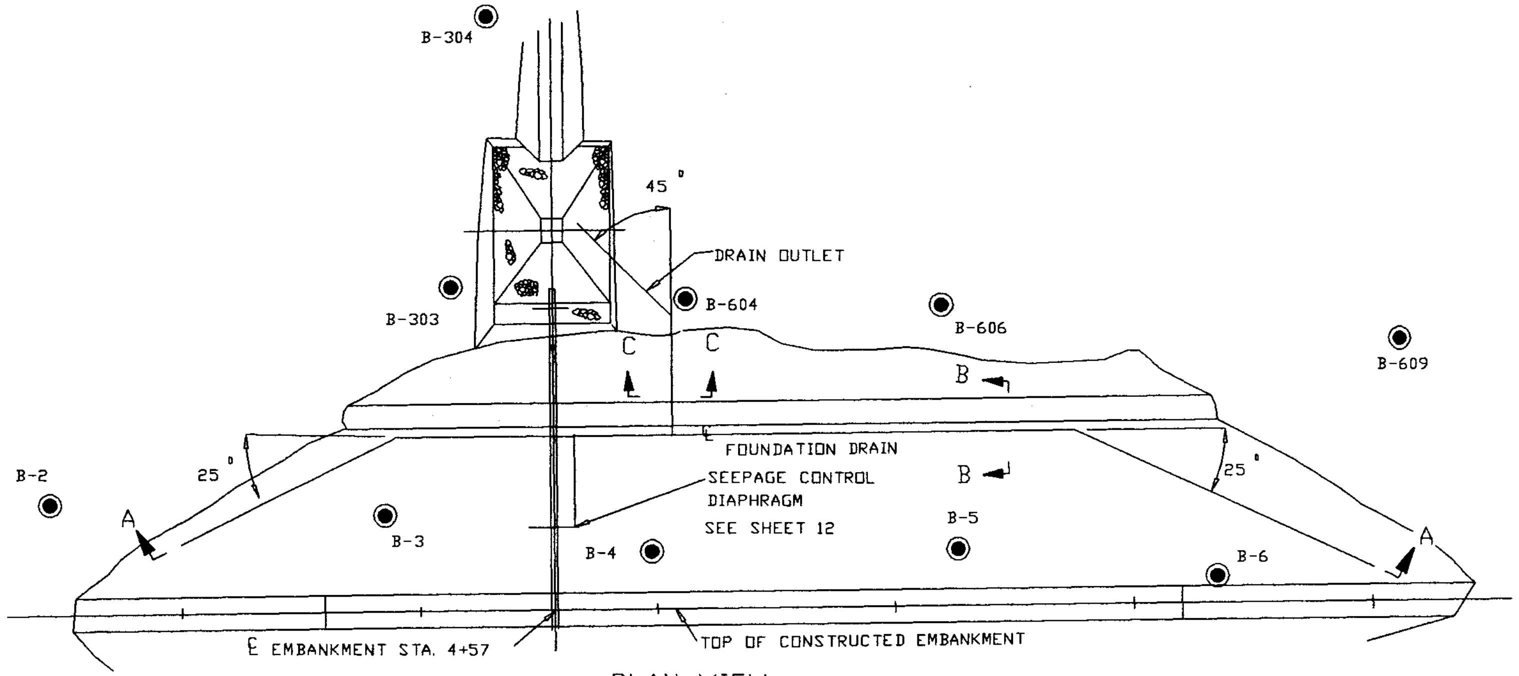
SEDIMENT CONTROL BASIN	SUM JOB
DRAIN FILL	3 CU. YDS.

NOTES:
1- NEAR THE COMPLETION OF THE EARTH FILL OPERATIONS, WHEN DIRECTED BY THE ENGINEER, THE SEDIMENT CONTROL DIKE SHALL BE REMOVED AND USED AS BORROW.
2- THE TUBING SHALL BE REMOVED FROM THE SITE.

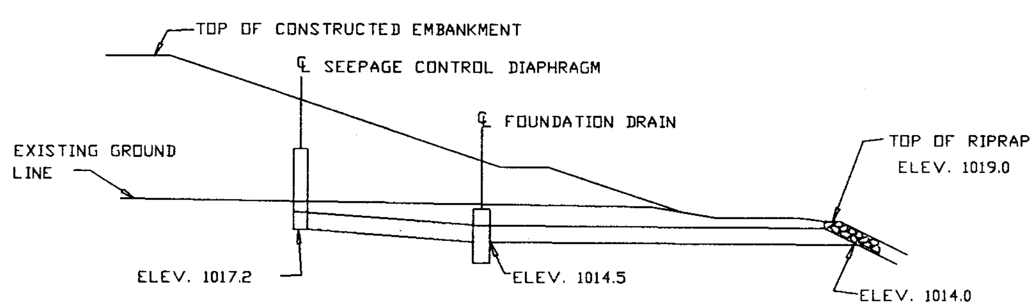
LAKE JIMMEL DAM
SEDIMENT BASIN DETAILS

SUPERB ENGINEERING, INC

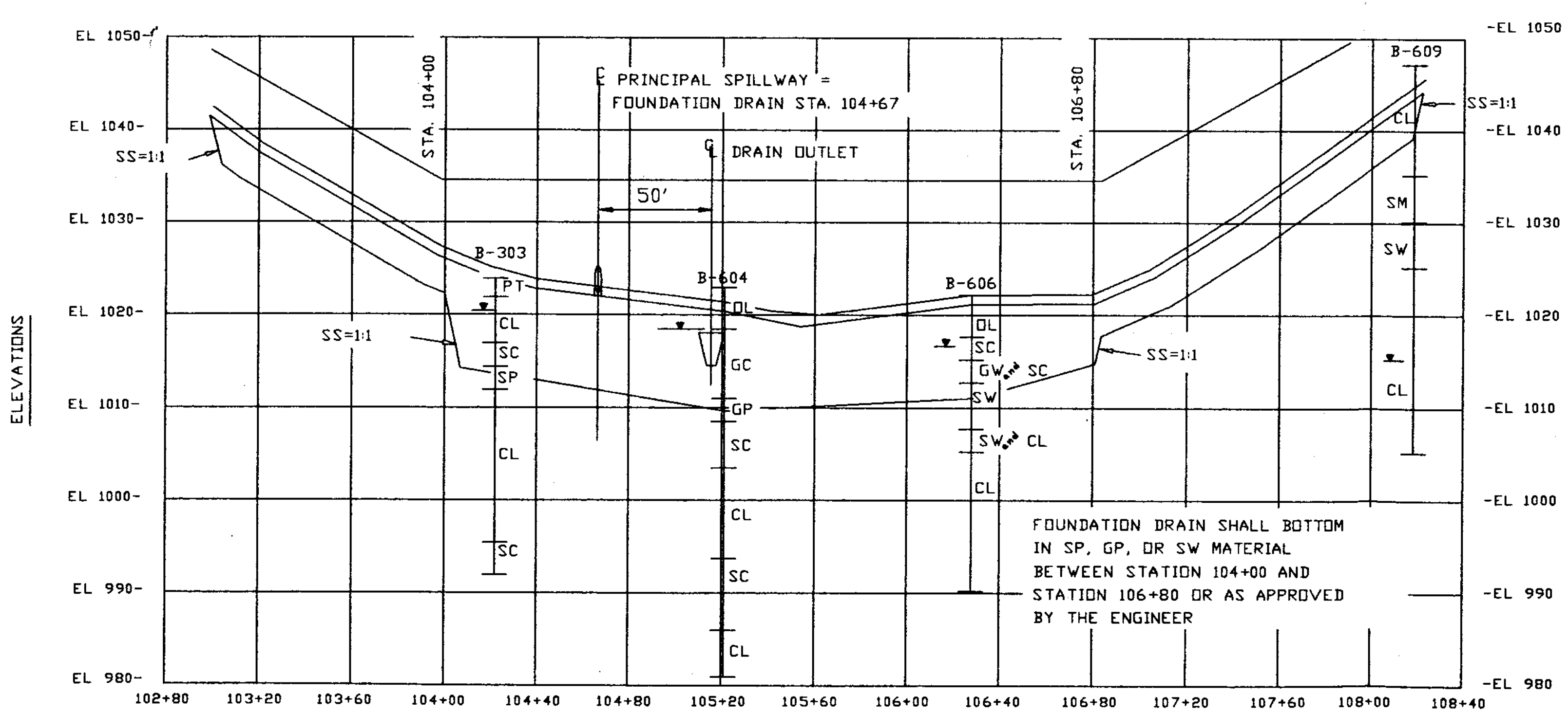
Designed	Approved By
Drawn	Title
Checked	Revision
Scale NOT TO SCALE	Sheet No. 10 of 15 · Drawing No.



PLAN VIEW



DRAIN OUTLET PROFILE



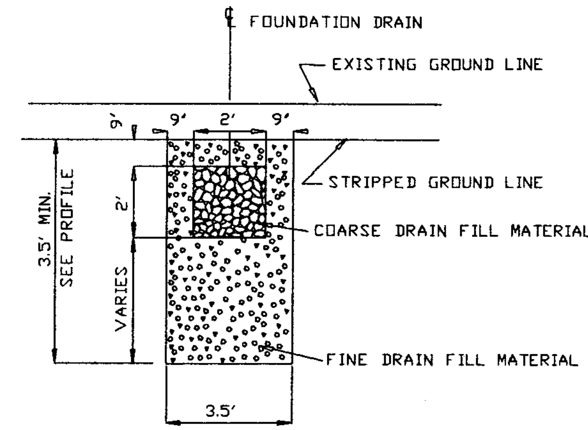
SECTION A-A

DRAIN FILL MATERIAL

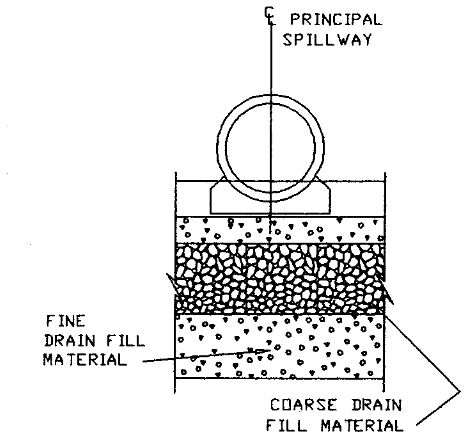
STANDARD SIEVE SIZE	COARSE % PASSING	AS-BUILT % PASSING	FINE % PASSING	AS-BUILT % PASSING
3	100			
1 1/2	85 - 100			
3/4	60 - 85			
1/2	30 - 60			
3/8	10 - 35		100	
#4	0 - 10		95 - 100	
#8	0 - 5		80 - 100	
#16	-		50 - 85	
#30	-		25 - 60	
#50	-		5 - 30	
#100	-		0 - 10	
#200	-		0 - 3	

COARSE DRAIN FILL REQUIREMENTS MAY BE MET BY USE OF INDIANA HIGHWAY COARSE AGGREGATE SIZE #5 .

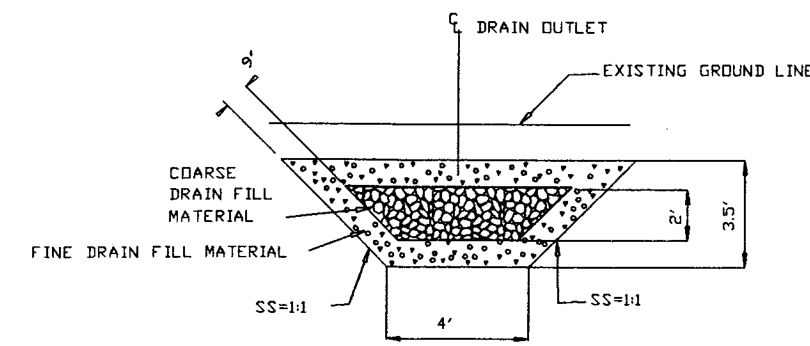
FINE DRAIN FILL REQUIREMENTS MAY BE MET BY USE OF INDIANA HIGHWAY FINE AGGREGATE SIZE #23.



SECTION B-B



DETAILS OF DRAIN FILL AT PRINCIPAL SPILLWAY



SECTION C-C

CROSS SECTION CONFIGURATION MAY BE INVERTED AT CONTRACTOR'S OPTION.

QUANTITIES

COARSE DRAIN FILL MATERIAL	42.0	CU. YDS.
FINE DRAIN FILL MATERIAL	430.0	CU. YDS.

LAKE JIMMEL DAM
DETAILS OF
FOUNDATION DRAIN

SUPERB ENGINEERING, INC

Designed
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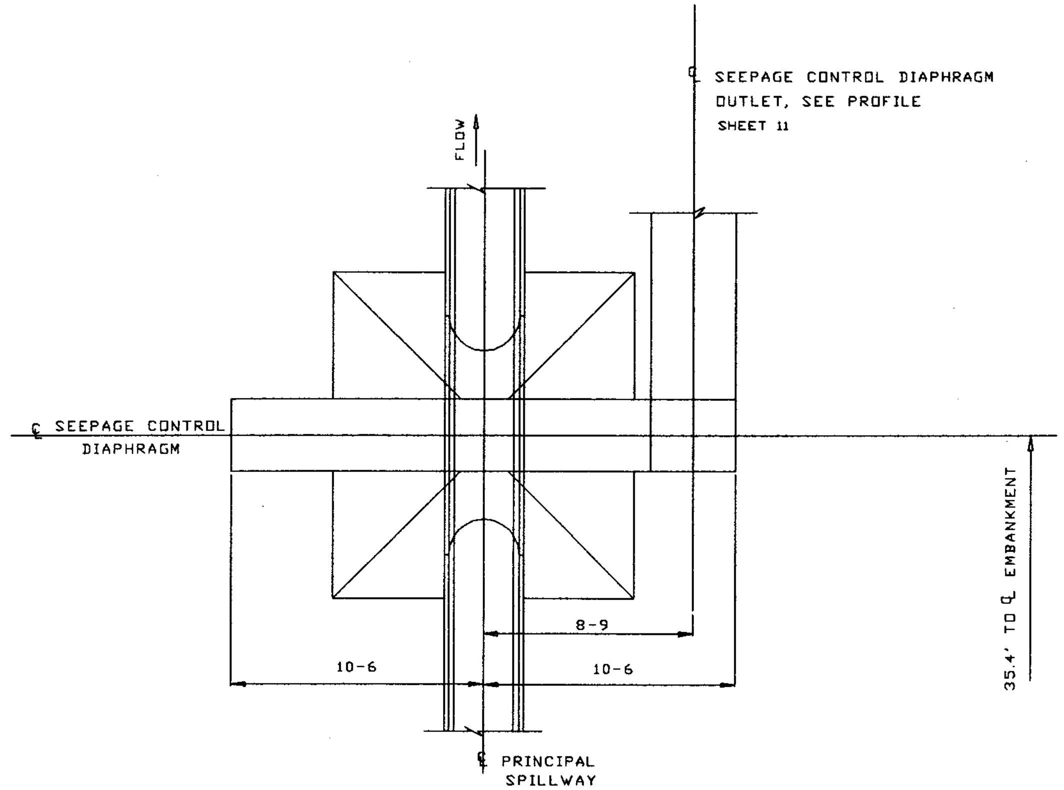
Scale NOT TO SCALE
Approved By
Title
Revision
Sheet No 11 of 15
Drawing No.



PLAN

SUGGESTED SEQUENCE FOR INSTALLATION OF SEEPAGE CONTROL DIAPHRAGM

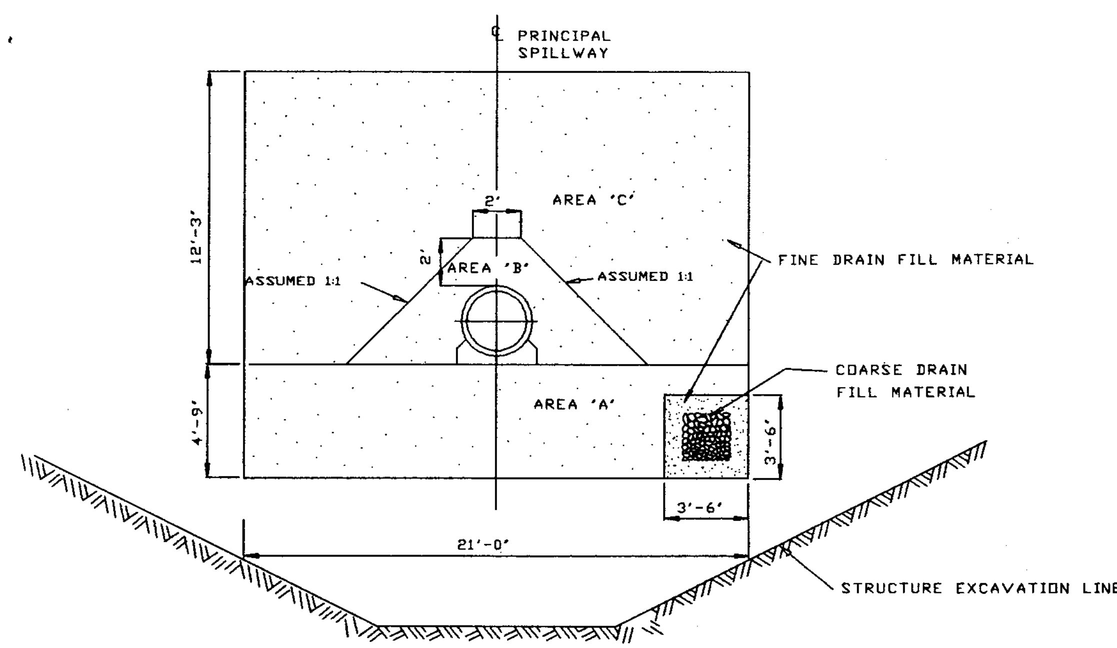
1-PLACE DRAIN FILL IN OUTLET.
2-PLACE DRAIN FILL IN AREA 'A' BELOW BEDDING SUBGRADE.
3-PLACE PIPE AND BEDDING.
4-PLACE DRAIN FILL IN AREA 'B' OVER PIPE AND BEDDING.
5-PLACE COMPACTED EARTH FILL OVER AREA 'A' AND AREA 'B'.
6-EXCAVATE TRENCH TO CONTACT CLEAN DRAIN FILL IN AREA 'A' AND AREA 'B', THEN PLACE AREA 'C'.

NOTES:
1- AREA 'A' AND 'C' MAY BE DONE IN LIFTS, THICKNESS AT CONTRACTOR'S OPTION.
2- THE DRAIN FILL SHALL BE WATER FLOODED IN ACCORDANCE WITH SPECIFICATION 24.

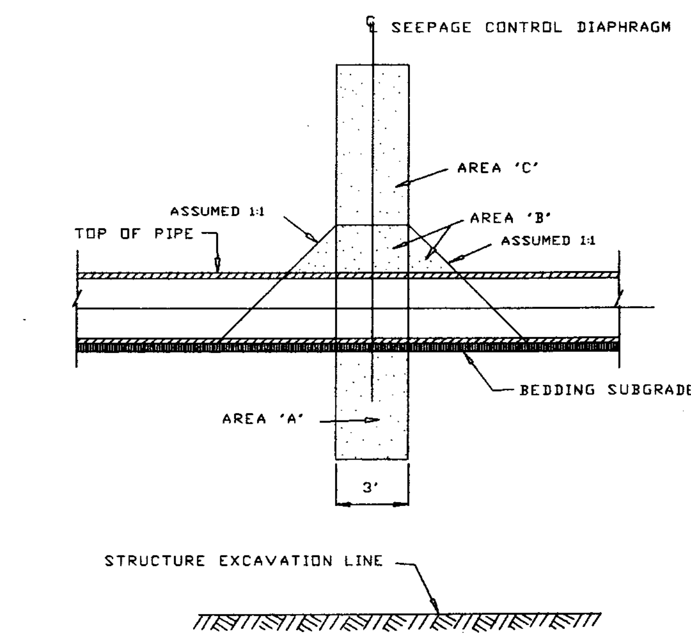
NOTE:
FOR FINE AND COARSE DRAIN FILL GRADATIONS, SEE SHEET 11.

QUANTITIES

FINE DRAIN FILL MATERIAL ________ 45.0 CU. YDS.



SECTION ON CENTERLINE OF SEEPAGE CONTROL DIAPHRAGM



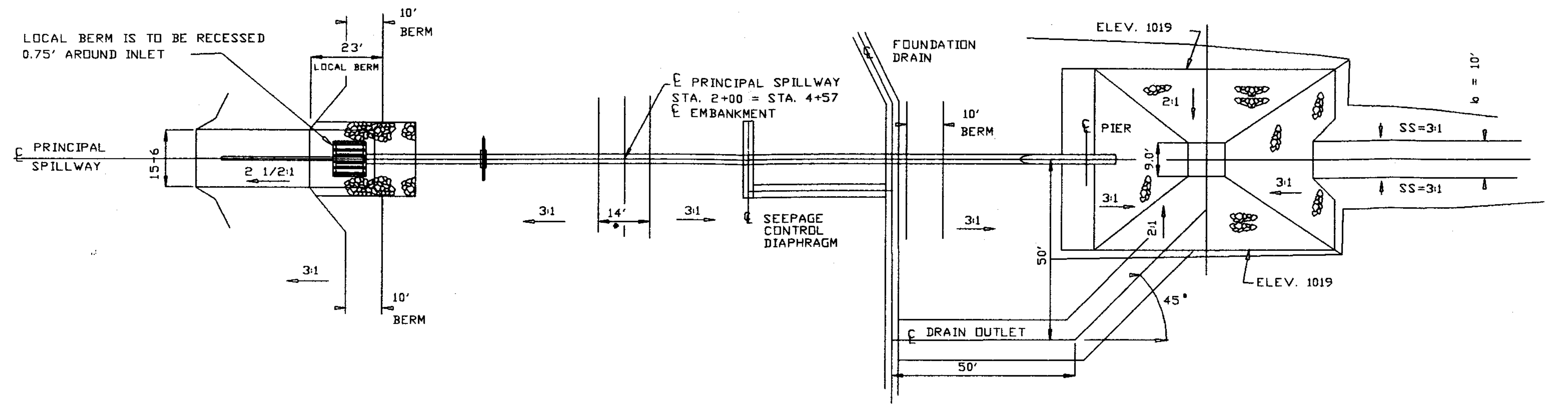
SECTION ON CENTERLINE OF PRINCIPAL SPILLWAY

0 4 8 12
SCALE IN FEET

LAKE JIMMEL DAM
SEEPAGE CONTROL
DIAPHRAGM DETAILS

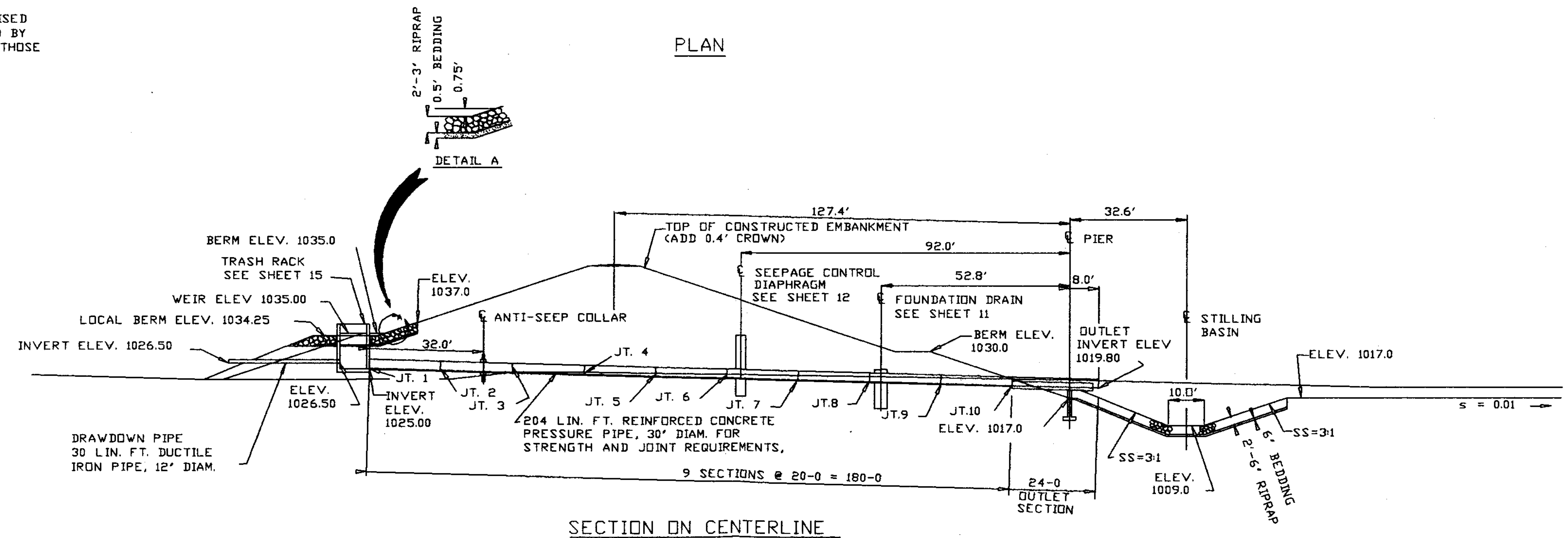
SUPERB ENGINEERING, INC

Designed		Approved By	
		Title	
Drawn			
		Revision	
Checked		Sheet No. 12 of 15	Drawing No.
Scale			



PLAN

NOTES:
1- STRUCTURE IS SYMMETRICAL ABOUT THE CENTERLINE, UNLESS SHOWN.
2-CAMBER CONDUIT IN ACCORDANCE WITH ELEVATIONS SHOWN.
3- EXCEPT AS PROVIDED FOR THE PIPE OUTLET, SHORTER PIPE LENGTHS MAY BE USED IN LIEU OF THOSE SHOWN WITH A MINIMUM PIPE LENGTH OF 8 FEET, USING APPROPRIATE JOINT EXTENSIBILITY. REVISED CAMBER ELEVATIONS WILL BE FURNISHED BY THE ENGINEER IF LENGTHS OTHER THAN THOSE SHOWN ON THE DRAWINGS ARE USED.



SECTION ON CENTERLINE

PIPE JOINT TABLE

JOINT LOCATION	INVERT ELEVATION	BEFORE BACKFILL DATE ____ INVERT ELEVATION	JOINT GAP	EMBANKMENT IN PLACE DATE ____ INVERT ELEVATION	JOINT GAP
JT. 1	1025.00				
JT. 2	1024.89				
JT. 3	1024.65				
JT. 4	1024.27				
JT. 5	1023.76				
JT. 6	1023.20				
JT. 7	1022.58				
JT. 8	1021.91				
JT. 9	1021.19				
JT. 10	1020.41				
OUTLET	1019.80				

QUANTITIES

PIPE CONDUIT - REINFORCED CONCRETE PRESSURE PIPE, 30" DIAM. INCLUDING CONCRETE BEDDING ____ 204 LIN. FT.

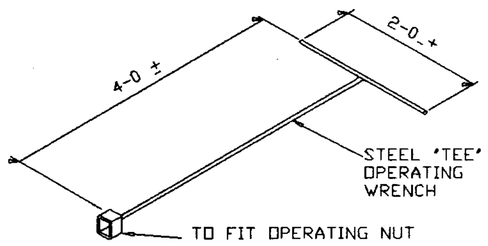
DRAWDOWN PIPE - DUCTILE IRON PIPE, 12" DIAM. INCLUDING FITTINGS ____ 30 LIN. FT.

20 0 20 40 60
Scale in Feet

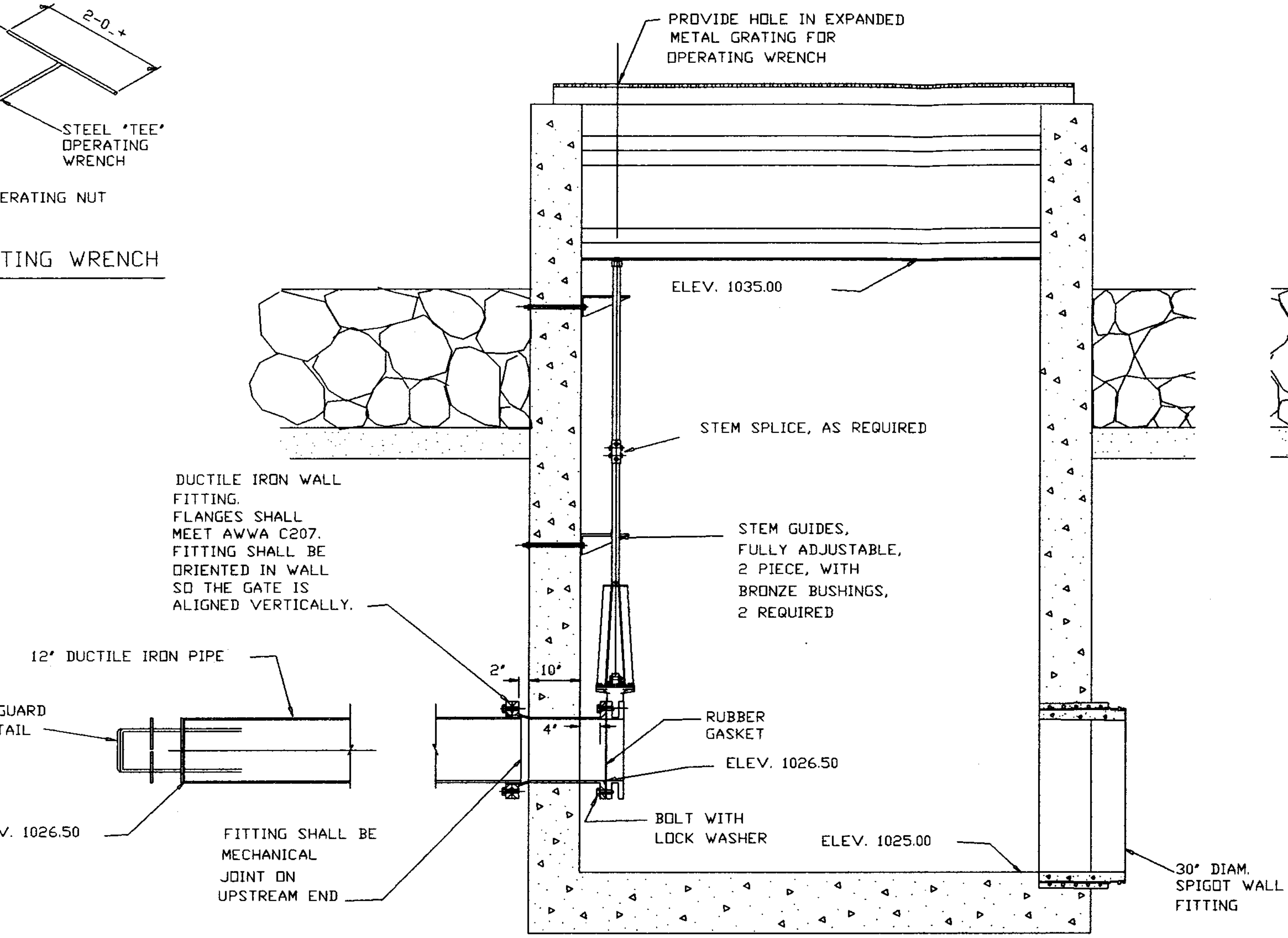
LAKE JIMMEL DAM
PRINCIPAL SPILLWAY
LAYOUT

SUPERB ENGINEERING, INC

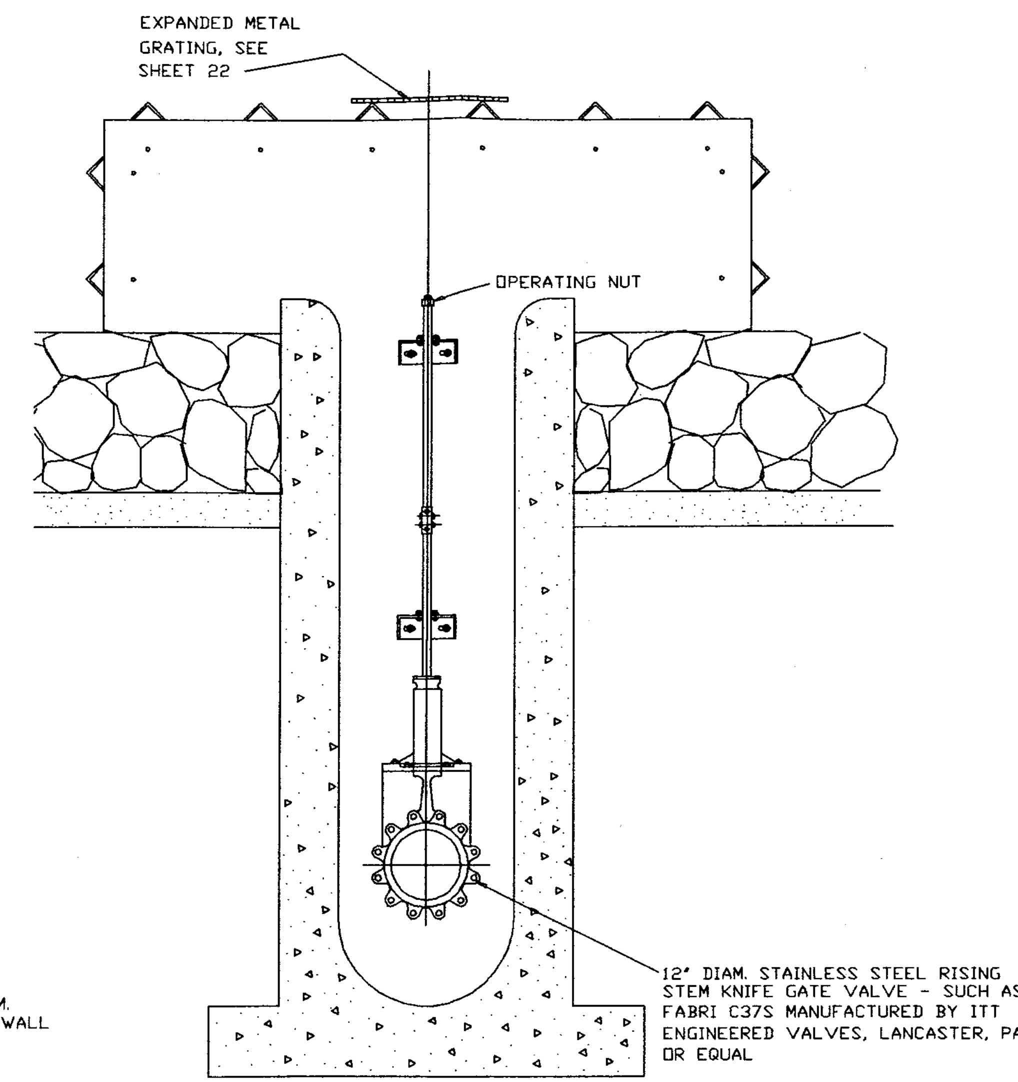
Designed ____ Approved By ____
Drawn ____ Title ____
Checked ____ Revision ____
Scale ____ Sheet No 13 of 15 Drawing No.



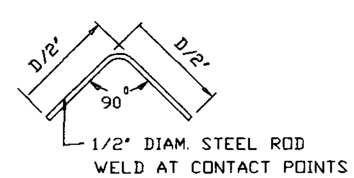
DETAIL OF OPERATING WRENCH
(1 REQUIRED)



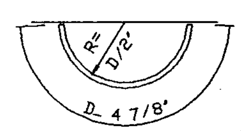
SECTION ON CENTERLINE



ENDWALL ELEVATION



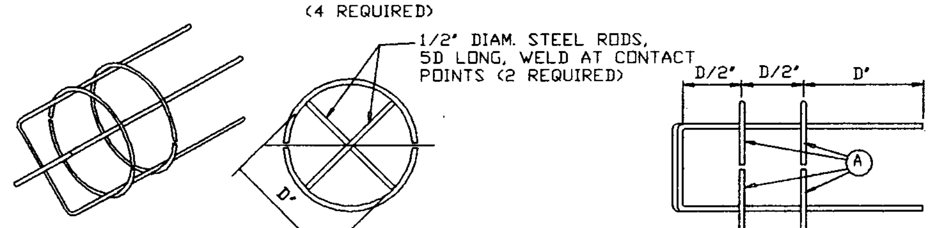
ALTERNATE DETAIL OF MARK (A)
(4 REQUIRED)



DETAIL OF MARK (A)
(4 REQUIRED)

QUANTITIES

KNIFE GATE VALVE, 12" DIAM. ________ SUM JOB



ISOMETRIC

UPSTREAM ELEVATION

SIDE ELEVATION

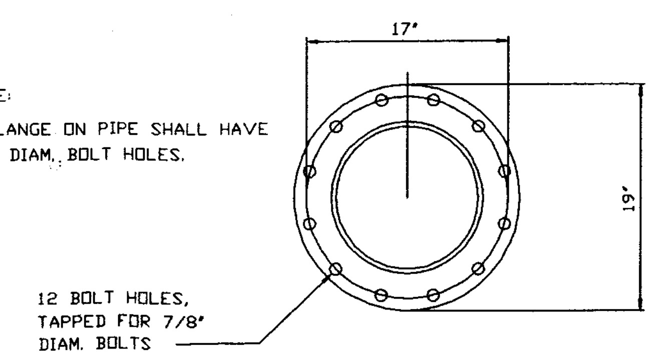
DETAILS OF TRASH GUARD
(TO BE SHOP FABRICATED AND GALVANIZED)

QUANTITIES

METAL WORK ____________ PART SUM JOB

NOTE:

FLANGE ON PIPE SHALL HAVE 1" DIAM. BOLT HOLES.

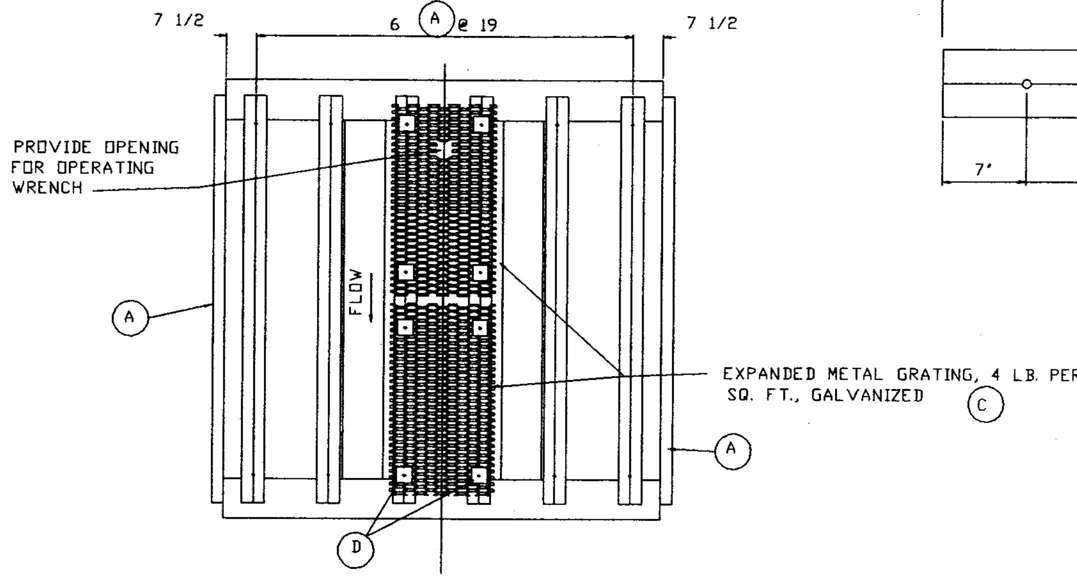


FLANGE DETAILS
(FLANGE THICKNESS = 1.25+0.12

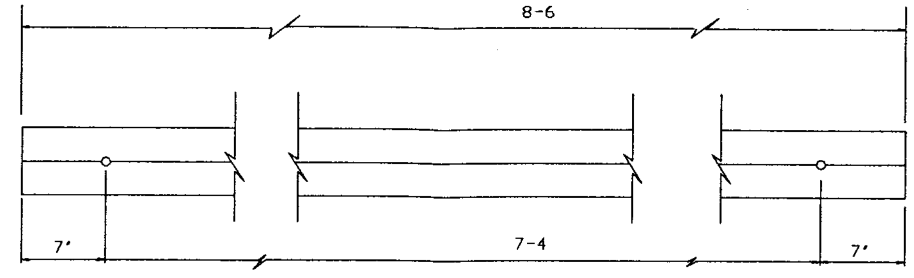
LAKE JIMMEL DAM
DETAILS OF 12" DIAMETER
DRAWDOWN KNIFE GATE

SUPERB ENGINEERING, INC

Designed ________	Approved By ________
Drawn ________	Title ________
Checked ________	Revision
Scale NOT TO SCALE	Sheet No. 14 of 15 / Drawing No.



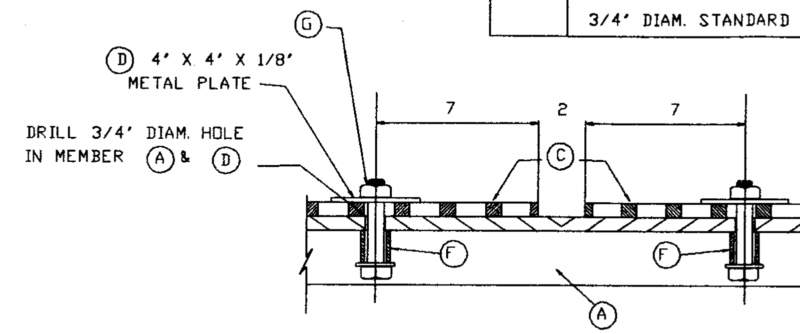
PLAN - TOP



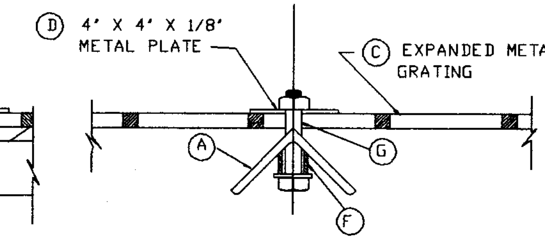
DETAIL OF ANGLE

MARK	ITEM	QUANTITY
A	ANGLE 4"X4"X3/8", 8'-6" LONG (GALVANIZED)	10
B	5/8" GALVANIZED ROD (SEE DETAIL OF ANCHORAGE FOR ANGLE)	20
C	EXPANDED METAL GRATING, 4 LB. PER SQ. FT., GALVANIZED 2'-0" X 4'-0"	2
D	4" X 4" X 1/8" METAL PLATE, DRILLED AND GALVANIZED	8
E	FORMED SPACER, GALVANIZED	16
F	FORMED SPACER, GALVANIZED	4
G	5/8" DIAM. BOLTS, GALVANIZED, LENGTH = 4" MIN.	4
	5/8" DIAM. NUTS AND WASHERS, GALVANIZED	40
	3/4" DIAM. STANDARD PIPE SLEEVE, 10" LONG, GALVANIZED	20

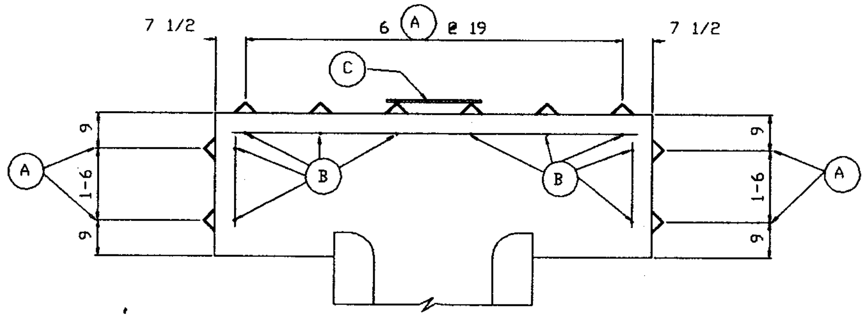
MATERIAL LIST



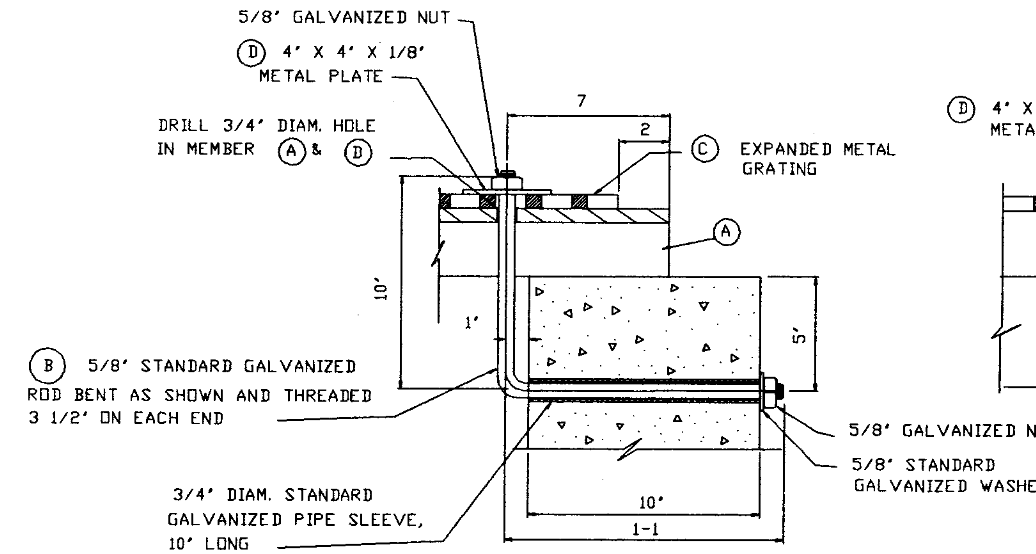
SECTION VIEW



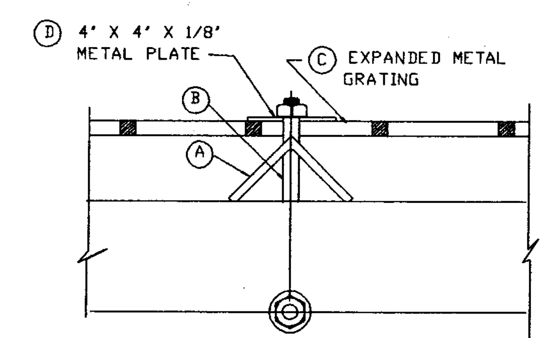
END VIEW



ENDWALL ELEVATION



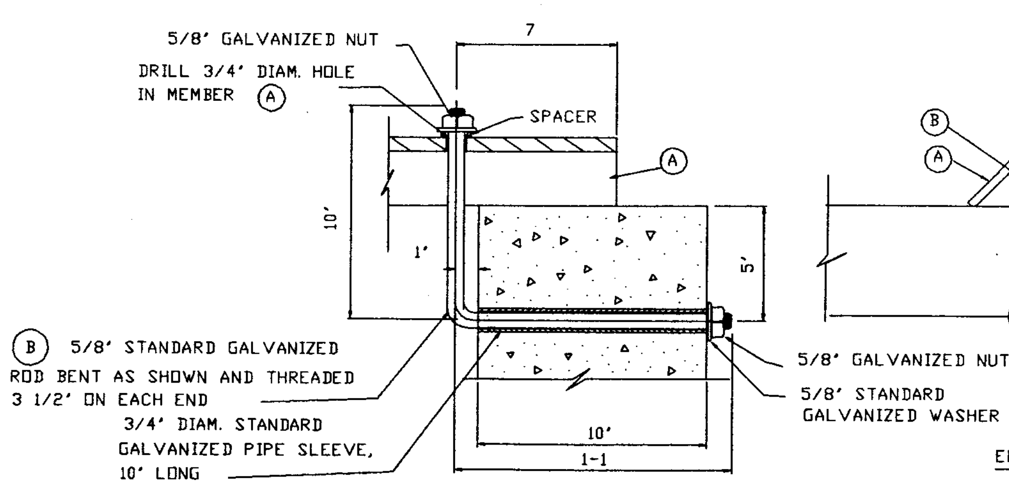
SECTION VIEW



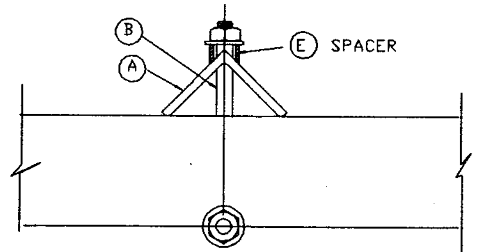
END VIEW

DETAIL OF ANCHORAGE FOR ANGLES

(ANGLES WITH GRATING)



SECTION VIEW



END VIEW

DETAIL OF ANCHORAGE FOR ANGLES

(ANGLES WITH SPACERS)

QUANTITIES

METAL WORK ____________ PART SUM JOB

LAKE JIMMEL DAM
DETAILS OF R/C INLET TRASH RACK

SUPERB ENGINEERING, INC

Designed		Approved By	
Drawn		Title	
Checked		Revision	
Scale	NOT TO SCALE	Sheet No 15 of 15	Drawing No.

PARTIAL LIST OF SPECIFICATION ITEMS FOR EXAMPLE DAM

Title

CLEARING
CLEARING AND GRUBBING
STRUCTURE REMOVAL
POLLUTION CONTROL
SEEDING AND MULCHING FOR PROTECTIVE COVER
MOBILIZATION
WATER FOR CONSTRUCTION
REMOVAL OF WATER
EXCAVATION
EARTH FILL
DRAINFILL
SALVAGING AND SPREADING TOPSOIL
PORTLAND CEMENT CONCRETE
STEEL REINFORCEMENT
REINFORCED CONCRETE PRESSURE PIPE SPILLWAY CONDUITS
DUCTILE-IRON PIPE CONDUITS
LOOSE ROCK RIPRAP
WATER CONTROL GATES
METAL FABRICATION AND INSTALLATION
FARM FIELD FENCES
GEOTEXTILE
AGGREGATE FOR PORTLAND CEMENT CONCRETE
ROCK FOR RIP RAP
PORTLAND CEMENT
AIR-ENTRAINING ADMIXTURES
WATER-REDUCING AND SET-RETARDING ADMIXTURES
CURING COMPOUND (FOR CONCRETE)
PREFORMED EXPANSION JOINT FILLER
SEALING COMPOUND FOR JOINTS IN CONCRETE AND CONCRETE PIPE
STEEL REINFORCEMENT (FOR CONCRETE)
REINFORCED CONCRETE PRESSURE PIPE
DUCTILE-IRON PIPE AND FITTINGS
METAL
GALVANIZING

Appendix F
Common Pitfalls

Common Pitfalls

The following is a listing of shortcomings that have been noted during the application and design review process. These are offered as an aid to ensure consideration has been given to all aspects of the design. Every item will not apply to each project.

- Not incorporating the geotechnical findings and recommendations into the plans and specifications.
- Not allowing the geotechnical contractor to review the final plans & specifications before submission
- Not providing a low level outlet for emptying the reservoir.
- Not providing a low level outlet large enough to drain the reservoir in a timely fashion.
- Not encasing or cradling the outlet pipe in concrete through the dam embankment (i.e. not eliminating the seepage path along the pipe).
- Pressurizing the outlet pipe by regulating the flow at the downstream end.
- Insufficient energy dissipation in the spillway
- Inadequate joints details for the concrete spillway slabs.
- Incompatible materials in the filter drains.
- Inadequate provision for differential settlement.
- Insufficient drainage and filters to control seepage through the dam and foundation.
- Inadequate shaping and preparation of the foundation for placement of fill materials.
- Not sloping the crest towards the upstream slope.
- Earthen spillways activating prior to the 50-year storm.
- Improper usage of filter fabric.
- Use of filter fabric for separation of coarse and fine aggregate.
- No animal guards on the toe drains.
- Not providing protection for any exposed PVC from UV radiation and vandalism.
- Improper conduit selection.
- Allowing blasting to take place in the vicinity of the dam without appropriate precautions.
- Not grouting abandoned boreholes used to evaluate existing dam that is currently impounding water.
- Not addressing instrumentation needs for monitoring during filling and normal operation, and other monitoring such as settlement during the construction process.
- Not providing adequate drop and/or projection of drain outlet pipes to allow for collection of seepage flows during monitoring and normal operation.
- Not addressing the need to ensure bonding between lifts of fill.
- Lack of adequate earthwork moisture control.
- Not providing berms on the downstream slope at appropriate intervals.
- No erosion protection at the abutment contacts (groins).
- Not providing for clearing 50 feet beyond the downstream toe of the dam.
- Not providing cleanouts on the interval drainage system.
- Not addressing seepage along the spillway conduits.
- Inadequate freeboard.
- Not addressing seismic stability issues including the riser structure.
- Not addressing the impact of utilities in the vicinity of dam.

- Using inadequate vegetation on the dam.
- Inadequate or no trash rack.
- Inadequate consideration of the impact of excavation within reservoir pool with respect to seepage control.
- Not evaluating the proposed dam over abandon coal mine areas.
- Not providing adequate erosion control prior to the establishment of a gravel ground cover.
- Not submitting as-built plans to the Division of Water.
- Allowing discharge from the emergency spillway to erode the toe of the downstream slope.
- Lack of consistency between plan sheets and supporting technical data (i.e. elevation and slope discrepancies).

Appendix G
Special Construction Monitoring Reports

A. Special Construction Monitoring Reports

1. Pressure Testing of Conduits

All conduits through the embankment should be pressure tested in accordance with the applicable ASTM and/or ANSI/AWWA Specification. A continuous record should be kept of all such tests and the information submitted for review should contain the following data:

Equipment - Equipment to perform the test.

Pressure and Duration - Specified testing pressure and minimum test periods.

Acceptance Criteria - Acceptable leakage criteria for test.

Records - A copy of the continuous record of the test and any re-tests.

2. Laboratory Material Certification

All drain and filter materials obtained from an off-site source should be regularly checked for compliance with the project specifications. Documentation should be provided that the materials supplied for placement in the dam meet the required gradation limits. Such documentation should include a certified copy of the suppliers' gradation tests. Synthetic filter material should be clearly marked for identification and include the manufacturer's certification number actually shipped to the job site.

3. Grouting

Evidence should be submitted that an acceptable grout curtain was constructed within the foundation of the proposed dam structure. To satisfy these requirements the report should contain the following information:

Drilling Equipment - Equipment that was used to drill the exploratory and grout holes.

Grout Equipment - Equipment that was used to mix the ingredients of the grout and pump the slurry down the holes.

Laboratory Equipment - Laboratory equipment that was used for on-site control tests.

Grout Mix Criteria - Specified performance values/properties of grout mix (es).

Trial Mixes - The results of any tests and trials that were made on a variety of grout mixes prior to the main grouting operation.

Design Mixes - The grout design mix(es).

Water Testing - The results of all water pressure tests in exploratory or grout holes.

Field Test Results - The results of all field tests conducted on each of the grout mixes during the grouting program with identification of non-compliant results and remedial action. Field tests should include, but not be limited to, sedimentation, slurry density, Marsh Funnel viscosity and unconfined compressive strength.

Profile - A longitudinal profile of the grout curtain showing drilling depths and grout takes for each stage of the grout holes.

4. Slurry Wall

Evidence should be submitted that a relatively impervious slurry trench cutoff was successfully installed within the foundation of the proposed dam. To satisfy these requirements, the report should contain the following information.

Excavation Equipment - Equipment that was used for construction of the working platform and for trenching.

Slurry Equipment - Equipment that was used for mixing the slurry.

Backfill Equipment - Equipment that was used for mixing and placing the backfill.

Test Equipment - Equipment that was used for the control tests.

Backfill Mix Design - Slurry backfill mix design.

Acceptance Criteria - Specified performance values/properties of slurry and backfill mix.

Field Test Results - Results of control tests, with identification of non-compliance results and remedial actions. Control tests on the slurry should include, but not be limited to, pH, unit weight, filtrate loss and viscosity. Control tests on the backfill shall include, but not be limited to, permeability, Atterburg Limits, slump, percentage passing the No. 200 sieve, water content, bentonite content and unit weight.

Profile - A longitudinal profile of the slurry wall showing excavation depths, materials excavated and backfill placed.

5. Blast Monitoring

It is assumed that all blasting operations should be conducted in strict accordance with existing ordinances and regulations. To ensure that no appreciable vibration was transmitted to existing structures or facilities a monitoring report should be prepared for each blasting event. This report should include, as a minimum, the following information:

Preblast Inspections - Documentation of any preblast observations.

Monitoring Equipment - List of equipment used to monitor the blast.

Time and Location - Date, time and location of blast.

Monitoring Locations - List of structures/facilities monitored.

Acceptance Criteria - Allowable vibration parameters.

Monitoring Records - Seismograph records and interpretation.

Post Blast Inspections - Documentation of any post blast observations.

Appendix H
Correction Form

Guidelines for Dams
Amendment Form

Name: ____

Address: ____

Phone and fax numbers: ____

The following sections, discussions, etc...should be included in these guidelines (provide as much detail as possible). ____
____
____
____

In reading the guidelines, I have noted the following errors (please indicate section as well as page number). ____
____
____
____
____

This form can be produced as needed. Please mail your completed form to:

Division of Water
402 W. Washington Street
Room W264
Indianapolis, IN 46204
Attn: Dam and Levee Safety Section
Phone 1-877-928-3755

You can also fax the complete form to us at (317) 233-4579.