SMALL STORAGE PROJECT FEASIBILITY AS AN ALTERNATIVE TO LARGE STORAGE PROJECTS

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LIST OF ABBREVIATIONS

AMC . . . . Antecedent Moisture Condition

ASTM . . . . American Standards Testing Methods

BIA . . . . .Bureau of Indian Affairs

BLM . . . . Bureau of Land Management

BREC . . . . .Bureau of Reclamation

CEQ . . . . .Council on Environmental Quality

CFR . . . . Code of Federal Regulations

CMP . . . . Corrugated Metal Pipe

CWA . . . . Clean Water Act

DOI . . . . .Department of Interior

EA . . . . Environmental Assessment

EIS . . . . .Environmental Impact Statement

EO . . . . Executive Orders

EPA . . . . Environmental Protection Agency

FEM . . . . .Field Engineering Manual

FERC . . . . . . Federal Energy Regulatory Commission

FLPMA . . . . Federal Lands Policy and Management Act

FONSI. . . . . Finding Of No Significant Impact

FR . . . . Federal Register

H & H . . . . .Hydrologic and Hydraulic

HEC . . . . Hydrologic Engineering Center

HECWRC . . . . . .Hydrologic Engineering Center Water Resources Council

HMR . . . . .Hydrometeorologic Report

MOU . . . . Memorandum Of Understanding

MRI . . . . .Mean Recurrence Interval

NEPA . . . . .National Environmental Policy Act

NFS . . . . National Forest Service

NOAA . . . . National Oceanic and Atmospheric Administration

NOI . . . . .Notice Of Intent

NPS . . . . National Park Service

NWS . . . . .National Weather Service

O & M . . . . .Operations and Maintenance

PIR . . . . .Public Interest Review

PL . . . . Public Law

PMF . . . . .Probable Maximum Flood

PMP . . . . .Probable Maximum Precipitation

PN . . . . .Public Notification

PVC . . . . Poly-Vinyl-Chloride

RCN . . . . Runoff Curve Number

ROD . . . . .Record Of Decision

S.W. .Surface Water

SCS . . . . Soil Conservation Service

SDF . . . . Spillway Design Flood

SDR . . . . Safe Drinking Water Regulations

SOF . . . . Statement Of Findings

T & E . . . . Threatened and Endangered

T_c .Time of Concentration

TR20 . . . . Technical Release 20

TR55 . . . . Technical Release 55

T_t . . . . .Travel Time

TVA . . . . .Tennessee Valley Authority

USBR . . . . .United States Bureau of Reclamation

USC . . . . .United States Code

USCE . . . . . .United States Army Corps of Engineers

USDA . . . . .United States Department of Agriculture

USDS-SCS . . .United States Department of Agriculture
Soil Conservation Service

USFWS . . . . United States Fish And Wildlife Service

USGS . . . . .United States Geological Survey

UV . . . . Ultra-Violet

WAPA . . . . .Western Area Power Administration

WDEQ . . .Wyoming Department of Environmental Quality

WPLC . . . . .Wyoming Public Lands Commission

WS . . . . .Wyoming Statute

WSEO . . . . .Wyoming State Engineer's Office

WWDC . . . . Wyoming Water Development Commission

ABSTRACT

Large storage projects in Wyoming are being delayed or denied by the regulatory framework in existence to the extent that they are not cost effective means of water storage. Because of this difficulty, less restricted means of storage are being sought. The feasibility of replacing larger storage projects with several small storage projects was studied in this thesis. It was found that small storage projects are not feasible as replacements for large storage projects, but are useful for other applications.

CHAPTER I
Introduction

PROBLEM STATEMENT

Small storage project feasibility is analyzed in detail in this thesis. The feasibility of small storage projects will be considered from a statutory level, initially; three sites are then chosen that best deploy any advantages the statutory search discovered. Finally, the three chosen sites are hydrologically and hydraulically (H&H) modeled to determine their H & H feasibility as alternatives to large projects, from a water development perspective.

BACKGROUND

The State of Wyoming's Water Development Commission (WWDC) has the responsibility of developing Wyoming's water resources. Because of the great difficulty in meeting the environmental, legal, and technical requirements for large storage projects, such as Deer Creek, Sandstone, and Smiths Fork, the Wyoming Water

Development Commission is interested in studying the permitting and hydrologic feasibility of smaller water development projects. The resource area for this study is headwater streams and isolated watersheds. The small storage facilities are small reservoirs that will be constructed as on-stream impoundments and off-channel impoundments fed by diversions.

PURPOSE

The purpose of this thesis is to explore three main areas of consideration - the environmental, legal, and technical requirements of these proposed small storage projects - to determine if there are sizes where the costs, due to regulations, begin to escalate. Since the Federal and political actions result from the interpretation of these regulations, they are considered ancillary to the three main points.

The ranking criteria for these regulations is dam height, with spatial extent coming into play as well. The regulations for siting a storage reservoir increase with the height of the dam. This progression of regulation will be used to determine at which dam height the project becomes unfeasible.

Unfeasibility is defined with respect to whether a project can be constructed as designed without the environmental, legal, and technical aspects driving the cost up to the extent the project can no longer be afforded by the constructing entity. Projects that become more cumbersome from a cost and regulatory standpoint fit into this category. These added costs deplete the money allocated to projects to such an extent that little remains for the actual construction after the legal fees have been paid.

This thesis was written in part to determine the dam height break points where statutes come into play that destroy a project's cost-effectiveness. Once these dam size break points are determined, projects can be designed to sizes that can be constructed without the added costs of the statutory red tape that larger projects encounter. The capacities of the storage projects will be a function of the regulatory environment, as well, but it is hoped that capacity can be related to dam height.

Three sites were then chosen, using the information from the statutory search. The small storage site selection process chose optimum sites, where the least red tape was encountered.

The three sites were modeled to determine if any one of them could function as a viable alternative to large storage projects that are problematic in the permitting process.

SCOPE

The scope of the statutory search will be limited to those agencies that come into play in the permitting process for storage projects. Since the code that authorizes and regulates these agencies is lengthy, subordination is necessary. The agencies, whose regulations and guidelines will be used, are discussed in a following section on literature review.

OVERVIEW

This thesis explored the regulatory framework involved when a storage project is proposed for permitting, and then determined if storage sites selected as a result of the regulatory search were of any value from a water use standpoint. This regulatory entanglement increases with the size of the facility. Regulation effects every aspect of an impoundment, from the water used to the land inundated. These regulations and their effects on projects for various dam heights are defined in the thesis.

Chapter II, Literature Review, indicates various Federal, State, and Local regulations that were studied to develop a statutory framework. These regulations are found in Chapter III.

Chapter III, Regulatory Feasibility, develops the statutory framework in place at the present time. This framework was used to decide on the size of small storage project that would come under the least amount of regulation, or would be the most feasible from a statutory point of view. In this chapter it is obvious the bulk of regulation applies to the six feet dam height. This indicates that all sizes of water storage projects will come under a lot of regulation. At the end of Chapter III is a summary of the results of the statutory review. The number of small storage sites along with other parameters derived from the statutory search were discussed.

Chapter IV, Rationale Behind Site Selection, develops the logic used to select the three sites to be modeled. The need for and the availability of water are two of many issues discussed in this chapter.

Chapter V, Data Collection, Methods of Analyses, Small Watershed Modeling and Simulation, contains the development of the parameters to be used in modeling the three drainage basins chosen as a result of the statutory search. The drainage basins were then modeled with and without small storage reservoirs, using Army Corps of Engineers (USCE), National Weather Service (NWS) and Soil Conservation Service (SCS) methodology to determine Hydrologic and Hydraulic characteristics.

Chapter VI, Results of Modeling, discusses the results of modeling the basins and their associated storage facilities. Flowrates, spillway sizing, and reservoir sizes were three of the topics discussed in Chapter VI.

Chapter VII, Analysis and Evaluation of Results of Modeling, considers the analysis of the data resulting from the basin modeling. Relevant generalities are discussed in this chapter.

Chapter VIII, Summary, Conclusions and Recommendations, discusses the findings of the thesis. This chapter also made recommendations that result from this thesis.

CHAPTER II
Literature Review

REFERENCE

To develop the progression of regulatory involvement, it was necessary to perform an extensive search of the literature and legal code. The various agencies that come into play in the permitting process each have their own authorizing acts and regulatory systems. It was necessary to study the various agency regulations to determine those regulations pertinent to storage projects. This was accomplished, in part, by meeting with various agency representatives in the agency's main State offices in Cheyenne. The representatives were questioned about permitting, and asked to provide the legal code pertinent to the regulations they had discussed. The regulations the agencies provided, supplemental sources from the State library, and information from telephone conversations was used to develop the regulatory climate that small projects are likely to encounter. Much of the agency authorizing and regulating code comes from the Code of Federal

Regulations (CFR), the Federal Register (FR), Public Laws (PL), United States Code (USC), Congressional Acts, Wyoming Statutes (WS), and Executive Orders (EO). These agencies, their acronym and their statutory regulation references may be found in Table 1. When these items are referenced in the text of the thesis, they will have a bracketed alphanumeric, such as, (33 CFR 320). This will aid the reader in finding the reference in the bibliography. These agencies have promulgated guidelines that are the basis for this statutory search. These guidelines resulted in an effective mechanism for helping to determine when a project will be feasible in a statutory sense.

Table 1. Specific Agency Regulations

AGENCY	ACRONYM	REGULATION / CODE
United States Army Corps of Engineers	USCE	33 CFR 320-330 & 33 CFR 220-230, Clean Water Act (CWA 404), Sections 9 and 10 of the Rivers and Harbor Act
United States Environmental Protection Agency	EPA	40 CFR 220-230, 40 CFR 1500-1520
United States Department of Agriculture	USDA	National Forest Service and the SCS are under the jurisdiction of the USDA
Soil Conservation Service	SCS	POND 378 a Technical Paper (TP)
U. S. Fish & Wildlife Service	USFWS	Threatened & Endangered Species Act (T&E), Federal Water Pollution Control Act (FWPCA)
Bureau of Land Management	BLM	PL 94-579, 43 CFR 2600-2620, 43 CFR 2520-2530, 43 CFR 2800-2880
National Forest Service	NFS	NFS Draft 7500 Series of June, 91
Bureau of Indian Affairs	BIA	43 CFR 2530
Wyoming Department of Environmental Quality	WDEQ	Clean Water Act (CWA 401)
Wyoming Public Lands Commission	WPLC	Wyoming Statutes (WS)
Wyoming State Engineer's Office	WSEO	Wyoming Water Law, Safety of Dams Act, Water Compacts, Treaties and Court Decrees

CHAPTER III
Regulatory Feasibility

BACKGROUND

The Wyoming Water Development Commission (WWDC) is researching the feasibility of using small storage projects in headwaters of small perennial, intermittent, and ephemeral streams. The regulatory feasibility of both on-channel and off-channel storage impoundments were considered, and the potential of such projects were evaluated.

CONCEPT

The concept behind the initial and secondary stages of this thesis was that as the dam height increases so does the size of the project. As the project size increases, so do cost, regulations, and concerns of political special interest groups. It was proposed that some clearly defined break points existed in the regulations that will delineate when a project of a certain size or less would be feasible and cost effective. It was those break points that were the concern of the statutory search.

DESCRIPTIONS AND DEFINITIONS

Headwater Stream : A headwater stream is considered to have a flowrate of less than or equal to 5 cfs. Headwater streams may be dry a good portion of the year. The district engineer of the United States Army Corps of Engineers (USCE) may establish headwaters to be the point along the course of a stream at which 5 cfs is the flowrate exceeded at least 50% of the time (33 CFR 330.2).

Isolated Watershed : Isolated watersheds, that would be used for off-channel storage, have basins that do not allow any large movements of surface water out of the basin by streamflow.

100 Year Storm : The 100 year storm is a precipitation event that has a Mean Recurrence Interval (MRI) of 100 years. This means the 100 year storm is the largest storm expected to occur on average in a 100 year interval.

Probable Maximum Precipitation : Probable Maximum Precipitation (PMP) is the largest theoretical precipitation event likely to occur in an area.

Probable Maximum Flood : Probable Maximum Flood (PMF) is the largest theoretically possible flood event that is likely to occur in an area. Often the event results from the PMP occurring under conditions that yield the maximum amount of runoff, such as under saturated soil conditions.

Spillway Design Flood : The Spillway Design Flood (SDF) is the flood used to design the capacity of spillways and other dam appurtenances. The SDF is a quantity that results from the application of the regulations for sizing spillways and is a function of risk to life and property. The SDF may be the PMF, a fraction of the PMF, or the results of modeling a precipitation event like the 100 year storm in the basin of the dam.

Hazard Classification : The Hazard Classification of a dam involves the likely outcome should the dam fail. Failure may be by overtopping or by breaching. Agencies all have various words they use to define how much of a hazard a dam poses to life and property, but basically there are three hazard classes. These hazard classes are High, Moderate and Low. Low Hazard Classification indicates failure of the dam would result in damage to the environment. Moderate Hazard Classification indicates, that in addition to environmental damage, there will be some property damage should the dam fail. Finally, High Hazard indicates that there is the probability for loss of life and extreme property damage if the dam should fail.

Public Interest : The public interest are those tangible and intangible items the public believes are worthy of safeguarding. The environment is an example of an issue the public has indicated is in the public interest. The public interest is defined by the representatives of the people through the laws they enact.

Administrative Dam Height : The administrative height of a dam is the height from the natural streambed to the top of the dam. This is different from the definition for dam height .

Dam Height : The dam height is the height from the downstream toe of the dam to the maximum water storage elevation. It should be noted that an SCS dam with an effective height of 35 feet and 5 feet of freeboard would be the same height as a National Forest Service (NFS) dam with an Administrative Height of 40 feet. The USCE defines dam height as from the lowest point on the dam cross section to the water level when the emergency spillway is operating at the design level.

Administrative Hazard Classification : Administrative hazard classification is a function of the height of the dam and the storage capacity (NFS 7511).

METHOD OF ANALYSIS OF REGULATORY INVOLVEMENT

The various codes that serve as the authority for the various agencies and form the guidelines these agencies use to regulate, were studied thoroughly. Throughout the reading, attention was paid to regulations pertinent to small storage projects. These pertinent regulations were compiled in an outline that categorized the regulations according to agency, code and dam height.

These regulations were then evaluated with respect to what size of impoundment structure the regulation would effect. The result of this type of categorization should be an inverted pyramid depicting more regulation as the height of the dam increases.

Similarly, the acreage inundated should increase as the height of the dam increases. This acreage inundated becomes an important parameter for some regulations. If acreage inundated can be related to dam height, only one independent variable (dam height) need be assessed, the process of feasibility assessment is simplified. When all the regulations are categorized with respect to dam height, project effectiveness from a statutory and regulatory perspective, relative to dam height, can be determined.

As mentioned earlier this cost effectiveness has three main components: the regulatory, the technical, and the environmental. Every one of these issues plays an important role in the determination of project feasibility.

The regulatory costs are costs that delay a project through legal debate, and require money for legal costs rather than for construction of the project. A project that illustrates to some extent these legal costs is the Deer Creek Project in Wyoming. This project is costing the taxpayers of Wyoming considerable moneys to defend the project against the allegations of violations of the court decree brought against the project by the State of Nebraska.

The technical costs are those associated with the construction and operation of the structure. It is fairly obvious that the higher a dam for a given dam site, the more water that is impounded. The higher the dam the more sophisticated the structure becomes. This sophistication, among other things, safeguards the public safety and interest. Regulations that specify the spillway design flood for a specific hazard type can have a large impact on the cost of the project. The difference between the size of a spillway necessary to convey the flood produced by a 100 year storm given a set of initial conditions, and the size of a spillway to convey a one-half Probable Maximum Flood (PMF) can be tremendous. It is obvious that the size of the spillway and its cost are at least proportional and in some cases exponential.

The environmental aspect of the costs results when adverse environmental impacts are judged to be high and the assessment and mitigation of these impacts becomes more involved. This involvement results in the National

Environmental Protection Act (NEPA) coming into play. With this involvement, the process becomes very complex and time consuming.

These are the cost factors to be considered. They are processes put into action for the public good, but often result in considerable cost to the public.

CRITERIA

The criteria for the statutory and regulatory search was dam height. This criteria was used to develop the decision making tool for the headwater area selection. The determining factors for the decisions were how heavily encumbered each level of dam height was with respect to the various regulatory agencies. Six (6) feet, twenty (20) feet, twenty-five (25) feet, thirty five (35) feet, forty (40) feet, one hundred (100) feet, and one hundred and fifty (150) feet were the height marks used to initially develop the decision making tool. These heights logically resulted from the regulations, and were derived from several different agency requirements. Various agency requirements will come into effect at these dam height break points, and will be discussed in the following sections.

It is important to note at this point that the regulations are bottom heavy. That is, the bulk of regulation applies to small dams. The six feet dam height that begins this discussion is the most regulation burdened category, and this six feet dam height is by far the bulk of this chapter. At higher dam heights, additional regulation is added to the regulation of the six feet dam height.

SIX FEET DAM HEIGHT

Six feet is the cutoff value below which the United States Army Corps of Engineers (USCE) will not inventory or inspect a dam, regardless of the storage capacity (33 CFR 222.8(h)(1)(1)). Even though any dam less than 6 feet will not be inventoried, it would require a State Permit Application under either the full permit process or the special permit process. These two State Permit Application processes will be discussed in the Section on the Wyoming State Engineer's Requirements. Additionally, many regulations can be germane regardless of dam height, and these will be discussed in this least restrictive category. The regulations developed in the lower dam height categories (for instance 6 feet) should be considered to apply to all dams heights greater (for instance 20 feet) than where the regulation is first discussed (at 6 feet). Those that begin to regulate at the next dam height level will pertain to the next higher dam height, and so forth.

These regulations accumulate with increasing dam height.

USCE NATIONWIDE PERMITS

Nationwide Permits are general permits for the discharge of dredge and fill material into waters of the United States granted on a national basis in accordance with 33 CFR 325. Part 325 determines when conditions are such that general permits can apply (33 CFR 325). The general permits are permits, of which the nationwide is a subset. The basic criteria for an activity to qualify for a general permit are that the activities individually or cumulatively cause minimal environmental damage and the activities are similar in nature. These permits can be conditioned by the district engineer to protect local conditions (40 CFR 230).

NATIONWIDE PERMIT 26

This nationwide permit deals with the effect dredge material can have on the surface waters of the United States, and in particular, sets acreage standards for permits. Nationwide Permit 26 states that any activity involving more than 10 acres of the Waters of the United States, including wetlands will require an individual permit. Further, Nationwide Permit 26 states that an activity effecting between 1 and 10 acres of such waters will require the district engineer of the USCE to determine if an individual permit is required. Finally, Nationwide Permit 26 sets up areas of exclusion. These areas of exclusion, including wetlands, are either above headwaters, or are not part of a surface tributary system to interstate waters - isolated waters - (33 CFR 330.5).

Nationwide Permit 26 indicates that if less than 1 acre of the Waters of the United States is effected by a dredge or fill activity, and that the area is above headwaters or is part of an isolated drainage, permitting is not required by the USCE. There are, however some problems.

With respect to the use of headwater areas and streams, Nationwide Permit 26 indicates that no permit is required for projects effecting less than one acre of Waters of the United States, including wetlands. This should be tempered by the response of Dennis Blinkhorn of the USCE, who stated, "the Corps will let the first project go; probably the second, but most likely when the third is proposed they will have to start looking at the cumulative impact. The project density would be a determining factor when cumulative impacts are considered." He also stated, "Waters of the United States should be read everywhere one sees navigable waters of the United States, even though, Flaming Gorge Reservoir is the only Navigable Waters of the United States in Wyoming."

Nationwide Permit 19

Nationwide Permit 19 allows dredging activities of no more than 10 cubic yards of material from Waters of the United States. Nationwide Permit 19 also states that it does not authorize the connection of canals or other artificial waterways to navigable waters of the United States. This indicates that the supply for projects located in isolated watersheds or off-channel would have to come from the basin by sheet flow, or be subject to the individual permitting process. Sheet flow from the isolated basin would be the only non-regulated water source for such projects (33 CFR 330.5).

State Clean Water Certification

It should also be noted that for the nationwide permits, State water quality certification is required for all activities that could result in any discharge into the waters of the State (33 CFR 330.9(a)). In the case of Nationwide Permit 26, State water quality certification is always required, but for other nationwide permits this certification may be required, but is not mandatory. This certification process involves the application of the Clean Water Act, Section 401, as required by the USCE. No permit will be granted unless State clean water certification is either granted or waived(33 CFR 330.9(b)(3)).

Furthermore, in order to have the right to water for the project, the Wyoming State Engineer must be involved, and the Wyoming State Engineer's regulations, laws, construction standards and permits must be adhered to. The USCE is required to see that State and local laws are observed (33 CFR 320.4(j)). This involves the transfer or acquisition of a water right for the project. A water right acquisition is needed when a new water allocation is being sought. A change of use or transfer is needed to change the use of the water. This change of use may be required when an out of basin transfer of righted water for another use in another basin such as an isolated watershed is attempted (WS 41-3-101,102,103,104). If an acquisition of a water right is not applied for and obtained, the water right belongs to the first legitimate applicant who receives the permit to use the water; not the first to use the water.

Scoping Process

Scoping is a process that determines which agencies will be involved and what issues are significant or insignificant. This narrows the discussion to pertinent important issues. The scoping process is a method of reducing the complexity of the EIS by reducing agency overlap and redundancy. The scoping process invites participation by various agencies that may have some jurisdiction with respect to the dredge and fill action. Scoping also allocates assignments necessary for the completion of an EIS (40 CFR 1501.7). Once scoping is completed, further simplification of the EIS may be accomplished by the tiering process (40 CFR 1508.28).

Individual Permits

If an impoundment in a headwater basin or isolated basin results in the alteration, or modification of more than 10 acres of wetland an individual permit is required. Individual Permits are a case-by-case application process. Activities requiring these permits are considered to have potential adverse environmental impacts. A district engineer of the USCE may require this case-by-case evaluation of wetland disturbances for wetland areas between 1 and 10 acres (33 CFR 223). If the district engineer deems it appropriate, they may require individual permitting for wetland disturbances of less than 1 acre. This is unlikely unless the area has unique or irreplaceable qualities, or provide irreplaceable habitat for T&E (Threatened and Endangered) species. In all Individual Permit procedures a minimum of an EA (Environmental Assessment) will be required.

EPA INVOLVEMENT

The Environmental Protection Agency (EPA) is authorized as an agency under the Council of Environmental Quality (CEQ) (40 CFR 1500). The National Environmental Protection Act (NEPA) process is a procedure required by the EPA to quantitatively and qualitatively assess potential environmental impacts.

The USCE is required to apply Environmental Protection Agency (EPA) b(1) guidelines to the activities seeking permits unless those activities are specifically excluded in the National Environmental Protection Act (NEPA). Excluded activities pose no significant individual or cumulative adverse environmental impact; by definition general permits, such as nationwide permits, should be included in this category. When the activity is not included in the exclusions it will minimally require an Environmental Assessment (EA), and possibly an Environmental Impact Statement (EIS). The process of determining to what extent the EPA becomes involved is indicated below (40 CFR 1501.3).

NEPA Process

If an activity is not covered by a general permit, or if it is determined that a general permit activity is more detrimental than originally thought, individual permitting may be required. Individual permitting requires the implementation of the NEPA process (40 CFR 1500). It is important to involve NEPA processes as early as possible in any process that effects the environment. The NEPA process applies various criteria to the activity to predict the potential for adverse individual or cumulative environmental impacts. NEPA processes require that alternate sites and methods be evaluated. Guidelines called b(1) guidelines, factual determinations, and toxicity testing are a few of the other evaluation criteria. Before the evaluation criteria are discussed, the NEPA criteria for determining the extent of EPA involvement will be considered.

ENVIRONMENTAL ASSESSMENT

If an EIS (Environmental Impact Statement) is normally required, it should be prepared. If the activity in question normally does not require an EIS and is not covered under a categorical exclusion, then an EA (Environmental Assessment) should be prepared. It should be remembered that an EA may be required whenever the district engineer of the USCE believes further evaluation is necessary, and that the EA may escalate to a full EIS if a FONSI (Finding Of No Significant Impact) is not the result of the EA's Statement of Findings (SOF) (40 CFR 1508.9).

Normally required, according to Dennis Blinkhorn, "Is what results from the case-by-case scoping process, where inter-agency cooperative impact assessment determines if the probable impact is such that an EIS is required. This inter-agency cooperative scoping process is more a function of policy, and if you will, precedent, than it is a function of discretionary authority. Discretionary authority has its own set of stringent guidelines." An EIS is normally required when inter-agency scoping determines that adverse environmental impacts, either individually or cumulatively, are significant.

Significant is defined with respect to the setting and intensity of the impact. For setting analysis, the local effects of the action are determined for both the short and long term. The intensity of an action is a function of the severity of the impact. Intensity is evaluated by weighing adverse impacts against beneficial impacts, by determining public health effects, assessing unique site characteristics, evaluating controversy, evaluating how certain the decision can be, analyzing cumulative impacts, analyzing impacts on cultural aspects, and evaluating effects on Threatened and Endangered Species (40 CFR 1508.27).

If in the NEPA process the EA route is chosen, the results will be either a Finding of No Significant Impact (FONSI), or a Notice of Intent (NOI). When a FONSI results from the process, the permit may be granted, if after the FONSI is posted for Public Interest Review (PIR), no substantial argument is lodged against the action. The PIR is a mechanism to involve the public in the governmental process by obtaining public comment concerning dredge and fill actions. Most often the EA will consist of environmental evaluation criteria, SOF, FONSI, PIR, and commenting in conjunction with the PIR.

If a NOI results from the EA, the project cannot be granted a permit without further study. This further study, triggered by the NOI, will be an EIS prepared by a lead agency (40 CFR 1501.3).

ENVIRONMENTAL IMPACT STATEMENT

Lead Agency

The lead agency is usually chosen because the proposed dredge and fill action most directly effects that agency's regulations (40 CFR 1501.5). The lead agency may be the agency whose permitting process is requiring the EIS. If more than one Federal agency is involved, a lead agency is chosen by five main criteria. These criteria are: the magnitude of the agency's involvement, project approval/disapproval authority, expertise concerning the action's environmental effects, duration of the agency's involvement, and sequence of the agency's involvement. These criteria are evaluated by the cooperating involved agency's, who are notified by letter or memo of their involvement. The involved agencies determine which agency is to be the lead agency in the EIS process. The selection procedure is to be carried out in an expeditious fashion (40 CFR 1505.5).

The lead agency has the responsibility of coordinating various agencies in fulfilling their requirements for the EIS process. The lead agency is also the agency that puts together the draft of the EIS, distributes this document for comment, conducts public hearings, responds to public comments, makes the final decision on whether to permit the action, and prepares the final draft for publishing in the Federal Register. Other agencies, whose interests are involved, are required to cooperate with the lead agency in an effective, efficient and expedient manner (40 CFR 1501.6).

The time periods for the various actions of an application requiring an EIS are as follows:

1. Within 15 days of receipt of an application the district engineer of the USCE will determine if the application is complete. If the application is complete the district engineer will issue a

Public Notice (PN) of the proposed activity if the activity is not exempt. If the application is not complete the district engineer of the USCE will send the application back to the applicant for completion(33 CFR 325.2).

2. A public comment period of 15 to 30 days will be allowed. Routine applications typically are allotted the 15 day period, while controversial applications are normally allotted the 30 day period. The time period may be lengthened or shortened by the district engineer of the USCE (33 CFR 325.2(d)).

3. The district engineer of the USCE has 60 days from the receipt of a complete application to issue a Record of Decision (ROD). This time period is exclusive of the extra time consumed by delays caused by other agencies in, for instance, the performance of the NEPA b(1) evaluation. These time over runs will be added to the 60 days the district engineer has to make a ROD. Evaluating agencies may ask for extensions to insure the data required of that agency is complete. If a ROD cannot be made on the application by the district engineer of the USCE, it will be referred to a higher level for a ROD

(33 CFR 325.2(d)).

What this indicates is that the timing for a ROD is difficult to assess. If the application is routine, the Public Comment Period may be cut to 15 days, and result in a ROD that could take considerably less than the 60 day requirement. On the other hand, if the application is for a controversial activity, it is likely that after the initial district level processes, that the matter will be referred to a higher level of the USCE. If this happens, the time to issue the ROD is anybody's guess.

Once an EIS is prepared by the lead agency using the appropriate guidelines, the lead agency must decide whether or not to grant the permit on the basis of the information available. This Record of Decision (ROD) (40 CFR 1501.4) is the result of a painstaking evaluation of the data collected during the NEPA process, the public and agency comments, and the application of required guidelines. These processes will be discussed in the following paragraphs. The extent of the data collection and agency involvement is determined by a scoping process, which will be discussed first.

Tiering Process

The Tiering process covers matters in a broader EIS with narrower statements or analyses, by referencing the issues to existing literature (40 CFR 1508.28). In this process only the pressing subjects are addressed; the related, but less important subjects, are not addressed in the statement, only referred to. This eliminates the use of "boiler-plate" legal text by referring interested parties to the location of the omitted text. This reduces the volume of an EIS to a more manageable level. In this way, Tiering provides a method to concentrate on specific and significant issues, rather than cluttering the issues with legal mumbo-jumbo. When the Tiering process is complete, the process of gathering the data required for the evaluation can occur. The various assigned agencies perform their tasks, and gather the data required of them. This requires that the information for the b(1) guidelines, factual determination, possible toxicity testing and other criteria, such as conformity to Executive Orders, be evaluated.

Table 2 illustrates the general sequence to be followed by Federal agencies in their assessment of probable impacts an action may have. The logic or reasoning for the criteria is listed along with the criteria. In addition to this evaluation, Executive Orders 11989, 11990, and 12291 are considered. The Presidential directives for no net change in the area of the United States covered by wetlands, development of wetland sites, and development of flood plains are contained in these Executive Orders. These Executive Orders basically discourage any development of wetlands or flood plains. For development to be permitted, it is often necessary to prove there is no alternative method of achieving the same goal. Where it is not possible to find an alternative site, replacement of wetlands is normally provided through mitigation (40 CFR 1508.20).

Table 2. List of Evaluation Issues *

Criteria	Logic
Minimization	Impact minimization should be a part of the design & construction concept
Factual Determination	Cumulative and individual impacts the action will have on: the water chemistry, the water circulation, the water turbidity, the water quality, the aquatic ecosystem, the site at the mixing zone, the cumulative effects on the aquatic environment, the secondary effects
If not covered by a general permit	
Alternatives	Examine practicable alternatives
Criteria Evaluation	Use criteria evaluation to select candidate sites
Evaluate Quality	Evaluate various chemical and physical components.
Contaminate Testing	If a contaminate exists, evaluate the type and quantity
Identify Alternatives	Identify those alternatives that are practicable and economically feasible
Document Factual Determination	Document the findings of the Factual Determinations for use in other documents.
Make a Document of Findings of Compliance	This document is the result of a comparison of the factual determination with the requirements of the discharge.

*Table 2 is derived from 40 CFR 230.5 and 40 CFR 230.11

Documentation is essential to establish knowledge about the extraction site and the fill site. The extraction site is the borrow site where the fill for the embankment is obtained. Usually, this extraction site is geographically close enough to the deposition site that filling would not introduce contaminants not present at the deposition site. Sometimes, however, formerly immobile contaminants may be released when filling with soil adjacent to the fill site. This is not a problem in most of Wyoming.

The level of documentation should reflect the level of impact and provide enough data to provide a concrete decision by the lead agency through the applicability of the guidelines (40 CFR 230.12).

B(1) GUIDELINES

General

The Clean Water Act, Section 404 (b)(1) guidelines are substantive criteria for evaluating discharges of dredged and fill material (40 CFR 230). The EPA requires certain environmental issues be evaluated for adverse impacts a proposed dredge and fill activity might have on the sites. These considerations include the b(1) guidelines.

The purpose of these guidelines is to restore and maintain the chemical, physical, and biological integrity of the Waters of the United States (40 CFR 230.1)(Wyoming Environmental Quality Act, 35-11-301(a)). These guidelines implement CWA 404 policies, which mandate that discharge of dredge and fill material into the Waters of the United States is not permitted unless it can be demonstrated that no unacceptable adverse impact will occur either cumulatively or individually(40 CFR 230.10). Filling of wetlands is considered one of the most severe environmental impacts covered by these guidelines (40 CFR 230.41).

The b(1) guidelines are used for the evaluation of individual permit actions, or of general permits actions which the district engineer for the USCE has decided should be considered on a case-by-case basis. General permits are considered on a case-by-case basis because of unforeseen individual or cumulative impacts that are more significant than was intended. In cases such as these, the district engineer of the USCE chooses an EA, which may or may not result in a FONSI, and thus, approval. If it is not approved, the EIS process ensues.

The b(1) guidelines help in the decision making by development of data through the evaluation of the key points. These key points are shown in Table 3 below. The information generated by the evaluation of the b(1) guidelines is the basis for the decision made, the ROD. If the data is insufficient to evaluate an action's environmental impact, the decision will be a denial, without prejudice, until sufficient data is provided (33 CFR 320.12).

The guidelines have several subparts, A-I. Each of these subparts has a specific purpose. Subpart A deals with evaluation required when an action is being considered for general permitting; Subpart B deals with the evaluation when an action is in compliance with the guidelines, and Subpart C deals with the chemical and physical characteristics of the site. The criteria for general permits have been discussed, as have the compliance standards. Table 3 will develop Subparts C through F (40 CFR 230.11 to 230.80) for those criteria that effect small storage projects.

Table 3. (b) 1 Guidelines

KEY POINT	OBJECTIVE	AGENCY INVOLVED
Subpart C	Parameter Determination	
Factual Determinations	Evaluate long and short term chemical, physical and biological effects of discharge	EPA, USCE USFWS
Physical substrate determination	Determine the effect the proposed discharge will have, individually or cumulatively, on the substrate (site) characteristics.	EPA, USCE USFWS
Water circulation, fluctuation and salinity determinations	Determine the nature and degree of effect the proposed discharge will have individually and cumulatively on the water circulation.	EPA, USCE USFWS
Suspended particulate and turbidity determinations	Determine the effect the discharge has on the suspended particle concentrations, both individually and cumulatively.	EPA, USCE, USFWS
Contaminate determination	Determine the degree to which the discharge introduces or relocates contaminates.	EPA, USCE, USFWS
Aquatic ecosystem and organism determinations	Determine the cumulative and individual impacts the discharge may have on the structure and function of the ecosystem.	EPA, USCE, USFWS
Determination of cumulative effects on the aquatic ecosystem	Determine the collective effects of a number of dredge or fill actions on the aquatic ecosystem.	EPA, USCE, USFWS

Table 3 (Continued)

KEY POINT	OBJECTIVE	AGENCY INVOLVED
Determine the secondary effects on the aquatic ecosystem	Determine the effects not directly related to the dredge and fill, but which contribute to the alteration of an ecosystem. A dam changes the water fluctuation of a stream.	EPA, USCE, USFWS
Subpart D	Potential Impacts on the Biological Characteristics of the Aquatic Ecosystem	EPA, USCE, USFWS
Threatened and endangered species	Plant or animal in danger of extinction over a large portion of its range is considered endangered. If the species is threatened with becoming endangered, it is threatened.	All Federal Agencies
Fish, crustaceans, mollusks and other aquatic organisms in the food web.	Suspended particles settling out can have an impact on oxygen levels, fish eggs, bottom dwellers, light levels and chemical levels.	EPA, USCE, USFWS
Other wildlife	Loss of breeding and nesting habitat, of escape cover, of travel corridors, and of preferred food sources.	EPA, USCE, USFWS

Table 3 (Continued)

KEY POINT	OBJECTIVE	AGENCY INVOLVED
Subpart E	Potential Impacts on Special Aquatic Sites	All Federal Agencies
Sanctuaries and refuges	Disruption of breeding activities, allow human access, introduce undesirable competitive species, and reduce necessary cover.	EPA, USCE, USFWS
Wetlands	Wetlands are areas for plants and animals that need saturated conditions to survive. Fill may effect biological productivity, water purification, flood reduction, and species diversity.	All Federal Agencies
Mud flats	Disruption of erosion or accretion can result in changes in biota, forage areas, nursery areas, chemical and biological exchange and decomposition of suspended materials.	USCE, EPA, USFWS
Vegetated shallows	Disruption of spawning and breeding areas, nesting areas, cover areas, feeding areas, nursery areas, and forage areas. Erosion protection can also be lost.	USCE, EPA, USFWS
Riffle and pool complexes	Reduction of aeration and filtration at the site and downstream from the site may effect the flow regime of the entire complex changing the quality and the habitat, and thus the inhabitant animals. May clog riffles and induce anaerobic conditions.	USCE, EPA, USFWS

Table 3 (Continued)

KEY POINT	OBJECTIVE	AGENCY INVOLVED
Municipal and private water supplies	Alter the taste, color, odor, chemical content, particulate concentration and otherwise render the water unsuitable for human use.	EPA, USCE, WDEQ
Recreational and commercial fisheries	Chemical contamination of recreational and commercial fisheries.	EPA, USCE, USFWS, WDEQ
Water related recreation	Discharges can destroy resources which support recreational activities.	EPA, USCE, USFWS, WDEQ
Aesthetics	Fill may encourage incompatible human access, degrade water quality, change odors, air quality and noise levels, elements that lead to the disruption of compositional harmony or unity.	EPA, USCE, USFWS, WDEQ
Parks, national and historical monuments, national seashores, wilderness areas, research sites, and similar preserves.	Disruption of the aesthetic, educational, historical, recreational, and/or scientific qualities thereby reducing or eliminating the uses for which the areas were set aside.	EPA, USCE, USFWS, NPS, NFS

Table 3 (Continued)

KEY POINT	OBJECTIVE	AGENCY INVOLVED
Subpart G	Evaluation and Testing	All Federal Agencies
General evaluation of dredge or fill material	Extraction site should be tested for chemical contamination, and possible contamination routes. When the discharge site is adjacent to the extraction site and is subject to the same contaminate routes, testing will not be required.	EPA, USCE, USFWS
Chemical, biological, and physical evaluation and testing	No single approach is totally effective. Biological-chemical interactive, water column effects, and effects on benthos are possible tests.	EPA, USCE, USFWS
Subpart H	Actions to Minimize Adverse Effects	All Federal Agencies
Actions concerning discharge site	The site should be chosen to minimize the effects on the aquatic environment. The effect of any plume should be minimized.	EPA, USCE, USFWS
Actions related to technology	Use of appropriate equipment or machinery, including protective devices to minimize the effect of the activity on the area.	EPA, USCE
Actions effecting human use	Use activities that minimize aesthetically damaging operations. Minimize altering the natural terrain by contouring dams to have low visibility, or make structures architecturally appealing.	EPA, USCE, USFWS

Table 3 (Continued)

KEY POINT	OBJECTIVE	AGENCY INVOLVED
Other actions	In case of dams, design water releases to accommodate the needs of fish and wildlife. The permitting authority should consider the ecosystem that will be lost in addition to the benefits of the new system.	All Federal Agencies
Subpart I	Planning to Shorten the Permit Processing Time	All Agencies
Advanced identification of disposal areas	Identify areas generally not acceptable for actions. Publicly post proposed action. Identify suitable sites. Maintain a record of suitable areas.	EPA, USCE, USFWS, WDEQ

Summary

Table 3 is derived from the Clean Water Act Section 404, the b(1) guidelines and 40 CFR 230. These are the basic CWA 404 b(1) guidelines that various government agencies use to evaluate the environmental impacts of dredge and fill activities. The agency evaluation is a result of the application of the b(1) guidelines to specific activities. Except when a general permit is involved, and the district engineer does not decide to consider the general permit on a case-by-case basis by invoking discretional authority, these will be the evaluation criteria used for dredge and fill sites

(33 CFR 330.8).

Agencies of b(1) Application

Most generally, the agencies involved in the application of these criteria will be the USCE, and through a Memo of Understanding (MOU) required by the Fish and Wildlife Coordination Act, and the United States Fish and Wildlife Service (USFWS)(Torbitt, May 91).

The USFWS functions to evaluate conformity with the Threatened and Endangered Species Act of 1973, the Federal Water Pollution Control Act Sections (FWPCA) 316 to 405, and the Federal Fish and Wildlife Coordination Act. The USFWS functions only to advise the USCE with regards to environmental issues. The USFWS has no authority to make decisions, but can apply to the EPA for a review of a USCE decision. If the USFWS does apply, and the EPA reviews and rejects the USCE decision, the EPA rejection will stand (33 CFR 320.4).

OTHER REGULATIONS

All Federal agencies are mandated by EO 12291 to reverse the loss of wetlands to no net loss, but the USFWS is the agency this policy most strongly effects. The USFWS in coordination with the USCE are the protectors of the wetlands of the United States. Wetlands are considered so vital to public health and welfare that they will be the major concern of any project, small or large (33 CFR

330.4(b)). This issue alone, will draw the USCE in to investigate if Nationwide Permits 26 or 19 are used for a series of small storage reservoirs. Wetlands are considered a serious issue, even in Wyoming, where wetlands are now believed to be 62 percent of what they were 200 years ago (Dahl T. E. 1990. *Wetland losses in the United States* 1780's to 1980's. Department of the Interior, Fish and Wildlife Service, Washington, DC). However, this percentage is not generally agreed upon by Wyoming.

RESULTS OF THE **NEPA** PROCESS

The application for dredge and fill will either be denied, accepted or conditionally accepted (40 CFR 230.40). Acceptance allows the activity to commence, but permission can be withdrawn any time the USCE or EPA finds that unforeseen impacts are causing damage or the permittee is violating the conditions of the permit. When permits are denied, an explanation of the reason the application failed, will accompany the rejection letter. An application may be allowed, subject to conditioning found necessary by the district engineer of the USCE or the Region Administrator of the EPA. A permit will never be allowed if a State's Department of Water Quality (WDEQ) will not certify the activity, or waive its jurisdiction (33 CFR 330.9).

BLM JURISDICTION

General

Two statements found in the United States Code (USC) restrict the indiscriminate use of public lands without employing the proper procedures for use and acquisition. These two statements are:

1. Public lands will remain in Federal ownership unless through land use planning it will serve the public interest if disposed of (43 USC 1701 Section 102).
2. Public lands will be managed in a manner that will protect the quality of the scientific, scenic, historical, ecological, environmental, air and atmospheric, water resource, and archeological values (43 USC 1701 Section 102).

This last statement makes it necessary to set aside certain public lands for preservation. Other regulations placed on public lands dictate that fair market value shall be obtained for the use of public lands, and that uniform procedures will be employed to arrive at these fees and their payment schedules (43 USC 1701 Section 102). There are several ways publics lands use can be acquired for small storage projects from the BLM.

Of the several ways to obtain the use of public lands for small storage projects, several will be mentioned briefly, but only the significant will be discussed in any detail. The Carey Act and the Desert Land Act have not had any authorized applications that have succeeded in several years according to the BLM office in Cheyenne, and are not considered major. This BLM office stated that the Desert Land Act should probably be considered a dead piece of legislation (Jerry Jesson, Jim Kohr). This act resembles the Homestead Act with a provision that the land must be reclaimed as well as improved. This act is similar to the Carey Act, which provides lands for those who reclaim them, except that this law is geared to the individual, whereas the Carey Act is geared towards the developer.

The Carey Act, legislation similar to the Desert Land Act, provides entities outside the Federal Government a method of segregating public lands for private use. The Carey Act, according to the BLM, has not had a viable entry since the Upper West Bench of the Bighorn River was attempted in the 1970's. Purchase, exchange, withdrawal, and right-of-way grants are other ways of obtaining public lands for beneficial use.

Desert Land Act

The Desert Land Act (43 CFR 2520-2530) should be considered a dead piece of legislation according to the BLM office in Cheyenne, WY. It has been such a long time since any application has been granted that it is safe to say, that without a significant advancement in technology, no future application will be granted under this Act.

This results because all lands have been picked over, and those lands suitable for reclamation have been reclaimed. There are no lands left that could be "proved up" by an "Entryman" to the extent required, without major technological advances.

Entrymen may acquire 320 acres of land unless the land is located within an irrigation district, in which case they may acquire 160 acres. Entrymen must pay 25 cents per acre for the land initially; this is in addition to any filing fees required. Entrymen must prove that a water right has been attained from a permanent and reliable source, sufficient to allow the cultivation of one-eighth of the land. Entrymen must provide further improvements to the land in the amount of one dollar per acre for the first three years. Before the fourth year, Entrymen may apply for the title to the lands if they have met the requirements stated above (43 CFR 2521.6). This Act was intended to encourage and promote the reclamation, by irrigation, of the arid and semiarid lands of the western United States through individual effort and private capital (BLM, DOI, WY-1122-16, March 1987, Information About;

Desert Land Entries).

CAREY ACT LANDS

General

The Carey Act provides a method of obtaining public lands through reclamation (43 CFR Group 2600). This Act designated 1,000,000 (one-million) acres of land to be set aside for reclamation by certain States in the arid West. An additional 1,000,000 (one-million) acres was set aside at a latter date for States whose first 1,000,000 acres was reclaimed. Wyoming has nearly the entire 1,000,000 (one-million) acres of the second segregation still available for administration under the Carey Act (43 CFR 2610.0-2(a)).

A State with Carey Act land may reclaim desert lands by constructing an irrigation system which provides sufficient water to grow crops. When this irrigation system is complete, the State may apply for patent to the lands, and open these lands to settlement (43 CFR 2610.0-3(a)). The settlers are allowed 160 acre parcels of land, of which, at least 20 acres (one-eighth) must be in cultivation(43 CFR 2610.0-7).

The State may recoup the cost of the development and costs of permitting by liens placed on the land to be paid to the State by the eventual settlers (43 CFR 2610.0-3(b)). Once the lands are properly developed, the title transfers to the State; when the settler pays the lien off it is transferred to the settler (43 CFR 2610.0-3(a)).

If the State fails to reclaim the mandatory 20 of 160 acres per settler allotment, the land reverts to Federal ownership (43 CFR 2610.0-7). These are the basics of the Carey Act. Some of the qualifying criteria are presented below.

This Act allows a State to apply for lands to reclaim. To do so, a plan of development must be formulated. This plan of development must follow a procedure that provides the following information:

1. economic feasibility of the reclamation plan,
2. adverse environmental impact avoidance or mitigation,
3. project plans with detailed conveyance structures,
4. and any additional data deemed necessary (43 CFR 2611.1-3).

If the plan is determined to be feasible, the application will be granted and the land segregated for 10 years. The construction to reclaim the land must begin within 3 years of application approval. Extensions of 5 years may be applied to the 10 year period to develop or "prove up" the land (43 CFR 2611.2).

The State must then acquire necessary water rights, construct irrigation systems and appurtenances, and may include the costs of such development in liens on the land that the settlers chose for inhabitation. These liens will be paid by the settlers to reimburse the State for development costs (43 CFR 2610.0-3(b)).

It has been some time since a feasible Carey Act application has been processed. In recent times, these applications are running into the same sort of difficulty as are the Desert Land Entries. It is unlikely that this will change, since it is the BLM who decides the feasibility of the beneficial use. This agency has found that the last Carey Act application could not provide enough water to significantly improve the proposed development.

WITHDRAWALS

Withdrawals transfer jurisdiction of land from one department to another (43 USC 1714). Even though no mention is made in the law specifying that the exchange be from one Federal department to another, it is assumed that both departments must be at the federal level. The land withdrawn is segregated out for a new and different purpose. For instance, a land may be withdrawn from National Forest Service jurisdiction and placed in BLM jurisdiction.

Any segregation of lands totaling more than 5000 acres requires Congressional approval. This acreage may be a single piece, or a collection of acreages for the same purpose (43 CFR 204(b)(1)). A notice explaining the new use, the land resource inventory, the land identity, the prior land use, the potential incompatibilities between new and old land use, the alternatives examined, consultation with other agencies, State and local effects, time limit, public hearing provisions (time and place), record's depository location, and geological report is required (43 CFR 204(b)(2)). A 20 year time limitation is placed on all lands withdrawn without a permit (43 CFR 204(b)(1)).

EXCHANGES

The DOI Secretary may accept title of non-federal lands for federal lands and transfer them out of public ownership if the best interests of the public is served (43 USC 1716 Section 206(b)). This law applies to the National Forest Service (NFS), which is regulated by FLPMA (Federal Land Policy and Management Act). If the exchange lands are under the jurisdiction of the National Forest Service (NFS) or the National Park Service (NPS) and are transferred to the BLM, the jurisdiction transfers to the receiving agency (43 CFR 206).

Right-of-Way

Right-of-Ways are probably the most applicable method of gaining use of public lands for the small storage project. These applications provide for the use of federal lands, except for wilderness areas, which require Congressional consent. These Right-of-Ways include easements, leases, permits or licenses to use or occupy, and use or traverse public lands granted for the purposes listed in Title V (43 USC 1701 Section 103(f)). The Secretaries of the Interior and Agriculture are authorized to grant, issue, or renew right-of-ways over, under, upon, or through lands under their jurisdiction for : reservoirs, canals, ditches, flumes, laterals, pipes, pipelines, tunnels, and other facilities and systems for the impoundment, storage, transportation or distribution of water (43 USC 1761 Title V).

Plans

Submission of plans, contracts, agreements, and other information related to use will be required for application of Right-of-Way (43 USC 1761 b(1)). The BLM normally accepts the State's requirements for dam, canal, and appurtenance works, but reserves the right to take issue with any specifications. If the State's regulations are more stringent than the agency guidelines, they are acceptable. If the State's criteria are not up to the agency standards, they will be required to be upgraded before the project can be permitted on the agency's lands. The National Forest Service has new minimum standards for dams on lands under their jurisdiction, and in the opinion of the author, it seems logical that the BLM will adopt many of the same criteria. These new regulations for the NFS will be discussed later in this thesis.

Where possible the BLM seeks to use a common corridor for utility right-of-ways. This common utility right-of-way theoretically will minimize the impact, by spatially limiting where right-of-ways can be located, when permitted (43 USC 1763). This provision may not apply to small storage projects, other than to eliminate from consideration sites that involve right-of-way corridors because reservoirs and conveyance structures may leak into buried utility lines. Topography also limits the location of channels and reservoirs. It is not known whether canals would be required to follow the right-of-way corridors, topography permitting, or whether leakage would adversely effect the other utilities of the right-of-way corridor.

The NEPA process will be implemented in all BLM right-of-way actions. The extent of the process will be a function of the size, location, and controversy of the project (43 CFR 505).

Impact Minimization

Minimization of impact is a concern for all Federal agencies, and the BLM is no exception. The Secretaries of effected agencies will consider National and State land use policies, environmental quality, economic efficiency, national security, and good engineering and technological practices when making decisions for permit applications (43 USC 1763 Section 503).

Rental Fees

The right-of-way holder shall pay annually, and when required, in advance, for use of a right-of-way. The amount to be paid is at fair market value, and is regionally determined. Most of the BLM lands in Wyoming's counties are rented at $4.49 /Acre/Year, with the exceptions of Crook, Hot Springs, Park, Weston, and Teton, which are rented at $13.46 /Acre/Year. This rent is for non-oil and gas type right-of-ways (Federal Register Vol. 52, No. 130 / Wednesday, July 8, 1987 / Rules and Regulations). Here, as in everything else, there are exceptions.

Exemptions to this fee payment schedule apply for those specified for Reduction or Waiver of Rental (Federal Register / Vol. 52, No. 130 / Wednesday, July 8, 1987 / Rules and Regulations). The entities that qualify for waiver or reduction include:

1. State and local governments when the right-of - way is granted for governmental purposes benefiting the general public, but not for the
2. Non-profit businesses or corporations not in any way affiliated with profit making organizations,
3. And in any case may be considered on a case-by-case basis.

Municipal utilities or cooperatives, except for the rural electric are not exempt from rent because they make a profit by charging customers for services (43 CFR 2803.1(i)). An entity may receive a reduction if it is determined that the fee would cause undue financial hardship. What is central to this issue is that State and Local governments are exempt as long as the project they undertake is for an organization whose goals are the public good and non-profit.

The money charged users of a right-of-way also includes permitting costs, such as the Environmental Assessment (EA) and possible Environmental Impact Statement (EIS), as well as filing fees. These moneys are subject to the same waiver and reduction rules as are the rental fees (43 USC 4321).

The holder of the Right-of-Way agreement is liable for damages or injury incurred because of their actions (43 USC 1763 Section 504 h(1)). The Federal government and the BLM assume no responsibility through the action of granting a permit for right-of-way. Any applicant not following the letter of the permit can have the permit for right-of-way revoked.

The general obligations of a permit holder to retain a permit for right-of-way, other than not abandoning the right-of-way, are :

(a)(i) Carrying out the purpose of the FLPMA Act;

(a)(ii) Minimizing environmental and scenic damage;

(a)(iii Complying with the environmental quality laws;

(a)(iv) Complying with the State's WDEQ, Safety of Dams Act, and Water Law requirements;

(b)(i) Protect Federal property and economic interests;

(b)(ii) Efficiently Manage the Federal lands; effected by the right-of-way;

(b)(iii) Protect the lives and property of the public;

(b)(iv) Protect the interests of the areas people;

(b)(v) Require the least damaging route be taken;

(b)(vi) Protect the public's interest. (FLPMA, section 505).

DAM AND RESERVOIR CRITERIA

The BLM in Wyoming allows considerable latitude in the design of dams and the hydrological and hydraulic modeling of a storage facility. The BLM will review projects built on lands under their jurisdiction. When they perform the engineering review, the BLM engineers use a Montana State Office of the BLM publication called "Surface Resource Facilities Handbook." This handbook has two parts:

1. Minor Earthfill Retention Reservoirs;
2. Major Earthfill Reservoirs.

This handbook has the SCS curve number criteria for modeling the watershed, and other empirical and well published formulas for hydraulic computation(Handbook, p57). With the exception of the items discussed in the next paragraph, the basic concepts of this handbook are identical to the SCS publication POND criteria. The side slopes of the dam are 3:1 face and 2:1 backside, as are POND's, but whereas POND states the requirement may be modified as materials dictate, the handbook specifies different sideslopes as a material property (Handbook, p54). The outflow equation is the same for both POND and the handbook. In general, the concepts are the same. The review of a proposed structure will allow a certain amount of flexibility in design, and consider alternate design methodology (Jesson, May 1991).

There are some differences that were noted in the handbook; they will be stated here. First, the cutoff collars will be designed to increase the average flow path by 20%, instead of the 15% found in the POND publication (Handbook, p58). Secondly, the topwidth of the dam is to be a minimum of 12 feet, and wider if a roadway is to be constructed (Handbook, p55). This compares conservatively to the 8 feet minimum requirement of the WSEO and the 10 feet minimum required by the NFS. Finally the formula for computing the topwidth is different, as follows:

$$W = 2*SQRT(H) + 3$$

Where: W = Topwidth

H = Dam Height

SQRT is the square root (BLM Handbook)

The review process considers all applicable design standards. Exact conformity to the handbook is not required. The handbook is used as a guideline by Wyoming BLM offices.

BLM CONCLUSION

The dam structural requirements are, with the noted exceptions, unremarkable. The BLM uses no set rules for the dams on its lands, and accepts alternate design procedures when not grossly inadequate.

The NEPA process will be followed for any action of any type by Federal agencies, and for any action of any type on the lands the agency administers. The BLM is required to implement the NEPA process in all BLM decisions regarding land usage on lands under BLM jurisdiction.

In general, the best method for obtaining the use of BLM jurisdiction lands is through the right-of-way easement permitting process. The Carey Act would provide some access to lands designated by the Act for segregation if the non-allocated water exists and could be developed. The Carey Act and the Desert Land Entry Act have not been good options to obtain the use of public lands for quite some time. The exchange process provides some opportunity to obtain Federal lands for State lands. This option would be more feasible than attempting to purchase Federal lands. This type of exchange would transfer lands from the Federal Government, where the land is regulated by Federal Lands Policy and Management Act (FLPMA), to the State, where the land would be regulated by the Wyoming Public Land Commission (WPLC). The WPLC also regulates the State Forests, and will be discussed in the State regulations. First, the National Forest Service (NFS) requirements will be discussed.

NFS JURISDICTION

The 6 feet dam height is the lower limit of inventory consideration for the NFS as well as the USCE. Dams less than or equal to 6 feet in height, regardless of storage capacity, or less than 15 acre-feet capacity, regardless of height may be excluded from consideration unless there is a potentially significant downstream hazard (NFS Draft Title 7500). This lower limit is the same as the USCE regulations. These low risk structures will generally be classified as Class D Projects.

The NFS regulations for dams and small storage projects is taken from a Draft of the regulations. This draft has a date of 6/21/91. The citing provided, indicates the source and the section numbering of this draft for dam specifications.

ADMINISTRATIVE HAZARD CLASSIFICATION

Administrative hazard classification is a function of the height of the dam and the storage capacity (NFS 7511).

CLASS D PROJECTS

Class D projects are dams less than 25 feet high and less than 50 acre-feet of storage capacity (NFS Draft 7511.1). From a volumetric and height standpoint these dams pose little risk if failure occurs (NFS 7511.2).

GENERAL

The NFS requires that an Environmental Analysis be performed for each project. The scope and intensity of the review are project dependent. The review depends on the complexity, extent and hazard classification of the project (NFS Draft 7512.1).

The NFS is not required to perform an engineering review for projects under the jurisdiction of the Federal Energy Regulatory Commission (FERC), United States Bureau of Reclamation (USBR) , USCE, or United States Department of Agriculture Soil Conservation Service (USDA-SCS) (Public Law 566 (PL 566) watershed protection and flood-prevention). Dams not located on NFS lands, but with reservoirs located all or in part on NFS lands, usually do not require an NFS engineering review, unless salient features require NFS involvement (NFS Draft 7512.2).

INDEPENDENT REVIEW

For regionally select moderate to high hazard dams an independent engineering review is required. This independent review provides a second opinion to the NFS review process (NFS Draft 7512.21).

REGIONAL DESIGN CERTIFICATION

When an NFS review determines that the design is adequate, the Regional Director will certify approval or acceptability of the project drawings and specifications. This certification of plans and specifications will occur prior to the use, and will be by signature. Special use applications will be prepared and stamped by a professional engineer with experience consistent with the project level (NFS Draft 7512.21). Washington level review is not required, but spot checks are performed for Safety of Dams Program monitoring (NFS Draft 7512.3).

Project Supervision and Scheduling

Qualified engineers are required for supervising site investigation, designing dams and transmission systems, monitoring the inspection of construction, safety inspections, emergency action plans, and operations and maintenance plans (NFS Draft 7513).

Compliance to NFS guidelines is required with respect to feasibility studies, EIS, site investigations, preliminary and final design and the forest planning. Coordination and review is required at all stages of construction (NFS Draft 7521).

Design Records

Design records must be kept neat and orderly to allow efficient review at any stage of construction. Design records must be kept complete and understandable, since they are often needed for design changes, EIS, and EA. The scope and detail of the design should reflect the project's complexity and risk. Design correspondence should be accurate and factual, and should contain information of all design alternatives examined. Final design summaries should provide a complete permanent design analysis and a decision record with an index (NFS Draft 7522).

Planning

Alternative sites and structure types should be considered to meet objectives and to minimize project costs, and social and environmental impacts. Planning should include minimum stream flow requirements, water rights, forest plans, project costs, hazard class and environmental factors. The NEPA process should consider these constraints as well as the benefits of the reservoir storage (NFS 7523).

General Design Standards

The level of detail increases from preliminary to final design, with increasing size, value, and hazard class. Design standards of the USBR, the USCE, and the SCS are acceptable on NFS lands. Generally acceptable standards may be approved on a case-by-case basis (NFS Draft 7524).

Hydrology and Flood Routing

USBR, SCS, National Weather Service (NWS) and other generally acceptable procedures appropriate for the dam site will be used for the design storm event to size the spillway of the structure. Special site specific considerations will be considered for accepting smaller inflow design hydrographs (NFS Draft 7524.1). Smaller inflow hydrographs may be used when documented analysis shows that overtopping the dam will not cause structural failure, or when failure of the dam will not result in additional damage as defined by an Incremental Damage Analysis discussed below (NFS Draft 7524.31).

Incremental Damage Analysis

An analysis should be carried out using two different routings of one spillway design storm (SDF). These routings are dam overtopping without failure, and dam overtopping with failure. These two modes shall be considered to determine if failure by overtopping with structural failure yields any additional economic loss, compared to overtopping failure without structural failure. Flows from downstream tributaries should be included in the model. The modeling should be carried downstream to a point where no additional incremental damage occurs (NFS Draft 7524.11).

HAZARD ASSESSMENT

High hazard rating, and tentative moderate or low hazard rating will be determined based on the clear weather breach flood damage from the dam to a point downstream where the flood is contained within the banks of the stream. The reservoir will be considered full to the brink of the emergency spillway when the breach occurs. Moderate to low hazard ratings will be checked for a high hazard rating based on an "Incremental Hazard Assessment" determined by routing the inflow design storm with and without a dam overtopping failure. If failure of the dam causes no additional economic loss, the structure will not be classified as high hazard.

SPILLWAY DESIGN

An uncontrolled spillway shall have a capacity to pass the spillway design flood (SDF). This flood is to be routed through a reservoir with the following initial conditions. For reservoirs without a flood pool, start the routing with the reservoir pool at the elevation of the lowest uncontrolled spillway. For flood control reservoirs, start the routing with the reservoir at the level the water surface would be after 10 days of drawdown from the 100 year flood pool. To develop a procedure for sizing the spillways, a decision tree has been formulated.

NFS EXHIBIT 2 - DECISION TREE

High Hazard Class

The most restrictive case of the tree is the High Hazard Class structure. For High Hazard Dams, the routing of a spillway design storm through the reservoir results in potential loss of life with or without dam failure, and loss of life is possible with an overtopping failure. Further, if a spillway cannot be built large enough for the SDF, the structure is of the High Hazard type. High Hazard types require a PMF (Probable Maximum Flood) be used as the SDF. If an existing spillway is capable of passing 75% of the SDF, then an increase in spillway capacity will not be required until the next major rebuild of the structure (NFS Draft 7524.32).

For other hazard classifications there can be no potential loss of life when the SDF is routed through the reservoir with and without dam failure. Further there can be no potential loss of life when the SDF is routed through the reservoir with or without dam overtopping failure. The SDF is then routed through the reservoir to determine the hazard classes for the other dams by the incremental damage assessment method. Incremental damage assessment results in the determination of the hazard class by applying the following definitions. It may be high, medium or low depending on whether the losses are mainly environmental (low), are somewhat economic (medium), or are very economic and life threatening (high). High water breaching should also be used in the incremental analysis as the comparison standard. Use the higher risk obtained from comparing the incremental damage analysis to the clear weather breach analysis. If there is no loss of life probable, and if the savings of constructing a spillway with less than SDF capacity is more than the cost of the anticipated downstream damages plus the cost of repairing the breached dam, then construct the spillway of the proposed SDF. Otherwise, use the NFS criteria that will be developed in the appropriate height criteria.

SITE INVESTIGATION

Intensity of investigation is a function of the hazard class of the dam, its size, and geologic features that could lead to higher risk. Low hazard and moderate hazard dams less than 40 feet high require test bores or pits penetrating one-half the height of the dam to be included in a field geology report. All other classes of dams require test bores to bedrock or 1 and 1/2 times the dam height to be included in the report. Adequate field testing of materials for stability and seepage is also required (NFS Draft 7524.41).

STRUCTURAL STABILITY

SCS guidelines may be use to design low hazard earth dam side slopes. Moderate to high hazard embankment stability shall be analyzed to demonstrate that all pertinent static and dynamic loading conditions will not exceed allowable shearing stresses in the embankment or the foundation. Factors of safety should be appropriate for the construction and operating conditions. In most cases embankments should be designed for unrestricted filling and drawdown rates (NFS Draft 7524.42).

EARTHQUAKE DESIGN

Earthquake design criteria should be considered in Moderate or High Hazard Dams in earthquake regions (NFS Draft 7524.43).

GEOSYNTHETICS

Low hazard dams may use geosynthetic materials as construction materials. Other hazard classes may use geosynthetic materials as permitted by the USCE, USBR, SCS, and the Tennessee Valley Authority (TVA) (NFS Draft 7524.44).

OUTLET WORKS

Outlet works must be capable of releasing the top five (5) feet of the reservoir capacity in less than five (5) days. Outlet works should be capable of draining at least two thirds (2/3) of the normal storage volume. When selecting pipe diameter for the outlet works, clogging and inspection must be addressed. Corrugated metal pipe (CMP) should be restricted to Class C hazard dams (dams less than 40 feet) unless otherwise restricted by the Regional Engineer. When CMP is used, life cycle cost estimates should be provided (NFS 7524.45).

FLASHBOARDS

Flashboards provide a means of raising the water level in a reservoir above the crest of the emergency spillway, when the spillway is not needed for releasing floods (Small Dams, 269). Flash boards with shear pins or failure supports are not permitted in uncontrolled spillways. Other types of flashboards must be approved by the Regional Engineer before use (NFS Draft 7524.46).

ACCESS

The access to reservoirs and their dams is a function of hazard class. High hazard dams will be serviced by an all weather road. Moderate hazard dams will be serviced by seasonal roads, and low hazard dams need only equipment access. Wilderness area access is considered on a case-by-case basis (NFS Draft 7524.47).

INSTRUMENTATION

Instrumentation should be considered that measures structural movements which may effect the safety of the dam. Instrumentation required is a function of size, hazard class, design, and foundation of the dam. Instrumentation used to detect foundation, abutment, and embankment changes should be considered. All instrumentation should be monitored during construction, initial filling and normal operation of the dam (NFS Draft 7524.48).

ADDITIONAL DESIGN ITEMS

Other design items should be considered for dams on NFS lands. Sediment storage should be addressed and allowed for, so the design life of the facility can be reached. Residual freeboard for wave action above flood stage should be provided, if necessary. Slope erosion protection should be provided for in the collecting watershed. Spillway erosion protection, and dam internal erosion protection should be designed for. Wave erosion protection can be provided for with log booms or vegetative growth. Embankment heights should be built to a constructed height that allows for consolidation. The crest width for earth dams should be designed to a 10 feet minimum width, and use W = (H+35)/5 for earth dams, otherwise (NFS Draft 7524.49). Wyoming's minimum crest width is 8 feet, and the formula for an earth dam's topwidth is different. The use of unlined earth or vegetated spillways should be limited to a frequency of once in every 50 years.

CONSTRUCTION MANAGEMENT

INSPECTION

Adequate inspection should be performed by persons trained for, and regularly assigned to, similar work. Independent design review teams may contact inspection teams, and inspect projects at their discretion (NFS Draft 7541.1).

Special Use Projects

The holder of the Special Use Permit will be required to provide inspection certification performed by competent personnel. The Forest Service will be required to insure that the permit holder's inspection team is adequate, and that the adjacent lands are adequately protected against environmental damage. The permit holder's engineers will be required to submit construction schedules to the NFS, and keep the NFS informed as to the construction progress. This allows joint inspections to be scheduled at critical periods of construction. The permit holder should inform State officials as to the project's progress, so joint inspections can involve appropriate State agencies (NFS Draft 7541.11).

Records and Reports

Special Use Projects

Permit holders are required to maintain daily inspection diaries, change order records for use in preparing as-built drawings, and material testing records. A certificate of construction shall be prepared for the NFS upon completion of construction.

Certification of Construction

Approval of drawings and specifications does not authorize operation of the completed works. The structure may be operated only after the Regional Director of Engineering of the NFS has certified in writing that the structure is acceptable for water storage or transmission, and approval is received from the qualified Forest Service Officer (FSM 7507). The engineer responsible for construction shall certify in writing that the works were built in conformance with the approved drawings and specifications. Additional approvals may be required by other agencies. The Regional Director will take action to verify compliance before issuing approval for operating the structure (NFS Draft 7541.3).

Inspection of Construction Operations

The primary responsibility for inspection rests with the special use permit holder, but the NFS may monitor the construction to verify the adequacy of the project.

FOREST SERVICE AND SPECIAL USE PROJECTS

Continuous Inspection

Continuous inspection will be required where the quality of the work cannot be determined by periodic inspection, or the work cannot be readily removed and replaced, if rejected. Such as:

1. Foundation excavation, when the depth must be determined during the course of work or when under water.
2. Placing compacted earthfill and filters.
3. Placing and bedding pipes.
4. Mixing and placing concrete.

Periodic Inspection

Periodic inspection may be suitable for certain other types of work depending on circumstances at the site, the construction schedule or the contractor's ability or attitude. Some of the work that lends itself to periodic inspection is:

1. Clearing and grubbing,
2. Stripping or structural removal,
3. Form construction;
4. Placement of steel reinforcement

(NFS Draft 7542.1).

MANAGEMENT SYSTEM

The management system provides for efficient and timely problem identification and problem correction for water storage structures.

PROJECT FILES

Project files are used to maintain up-to-date information on problems, risks, repairs, operation and maintenance (O&M) changes, instrumentation, and inspections for NFS permitted dams. The responsibility for maintaining the file rests with the permit holder, but the NFS will maintain a partial file of inspections, maintenance performed and agreements (NFS Draft 7552).

OPERATION AND MAINTENANCE

Operation and Maintenance plans are required, and are the responsibility of the permit holder to prepare. Plans for new construction should be prepared in the design stages (NFS Draft 7553).

OPERATION PLAN

Operation plans should reflect current operating agreements; if they do not, they should be revised to reflect changes in the project status or maintenance condition (NFS Draft 7553.1).

Special Use Structures

The authorized permit holder should prepare an operation plan that coordinates State agencies. The plan should be reviewed and approved by qualified engineers. Monitoring by a qualified engineer is required at a frequency of no greater than 5 years, and shorter for high hazard and controversial structures (NFS Draft 7553.11).

MAINTENANCE PLAN

Maintenance plans must be reviewed and updated periodically to insure current conditions are covered (NFS Draft 7553.2).

Special Use Structures

The authorized permit holder is responsible for the preparation of a maintenance plan. This plan will include the involvement and coordination of the various appropriate State agencies. The plan is subject to review by the NFS engineers or duly appointed representatives.

Maintenance Categories

The three categories for maintenance are Priority 1, Priority 2, and Routine. Priority 1, or emergency maintenance, is for structures needing immediate and critical repair for the public's safety. Priority 2, or non-emergency maintenance, is for structures where more costly repairs and unsightly damage can be averted by performing maintenance now. The public safety is not an issue in Priority 2 type maintenance; only the prevention of more costly future damage. The final category of maintenance is Routine Maintenance. This category is the minor housekeeping type maintenance normally addressed in the maintenance plan (NFS Draft 7553.22).

INSPECTIONS

Inspection is necessary to identify the routine maintenance. Periodic inspection can disclose conditions that might threaten the life and property of others, so that timely corrective action may be taken. Because some States and municipalities have regular inspection programs, it is more efficient to perform joint inspections to prevent the duplication of work. These joint inspections should include other appropriate governmental agencies, where possible.

The Federal guidelines for Dam Safety describe three frequencies and types of inspections. These are Informal and Special Inspections, Operations and Maintenance Inspections, and Safety and Hazard Assessment Inspections (NFS Draft 7554).

INFORMAL AND SPECIAL INSPECTIONS

Informal Inspections

When employees are in the vicinity of dams, they should observe the overall condition and function of the structure. They should look for leakage, erosion, sinkholes, boils, seepage, slope instability, undue settlement, displacement, tilting, cracking, deterioration, and improper functioning of drains and relief wells (NFS Draft 7554.11).

Special Inspections

Special Inspections are to be performed after unusual events occur that might effect the safe operation of the structure. These events include earthquakes, unusually large flood flows, sabotage, or unusual events reported by operators or informal inspectors (NFS Draft 7554.12).

OPERATIONS AND MAINTENANCE INSPECTIONS

A qualified engineer shall periodically review inspection records, observe operation and maintenance procedures, and inspect structures on NFS lands. A maintenance report will be prepared for each NFS dam for scheduling routine maintenance, programming special repairs, and updating the inventory. Special use structures shall be required to have owner acquired inspections in accordance with the inspection plan provided for in the authorizing permit. State or local inspection reports are usually acceptable. To verify compliance with the operating plans, a log and water stage record, or metering device record should be checked periodically throughout the year (NFS Draft 7554.2).

Operations and Maintenance Inspection Schedule

Operation and maintenance inspection scheduling depends on many factors such as the type of structure, the hazard rating, the watershed characteristics, the climate, the purpose of the reservoir and the type of spillway.

A reasonable and workable inspection schedule will be established by the NFS. The schedule will be based on conditions particular to the structure, the need for coordination of the work with other Forest Service inspections and evaluations, and National and Regional guidelines and standards. High Hazard Dams will be inspected at least annually, and also following earthquakes and unusually high runoffs (NFS Draft 7554.21).

Follow-up Action

When an inspection discloses operation and maintenance deficiencies, the Forest Service Supervisor shall take appropriate action. This action will include establishment of a reasonable maintenance schedule based on the priority of the maintenance required and a program of appropriate restoration and repair. The action will also include informing the owner, promptly by letter, of the deficiencies. Copies will be sent to the appropriate Federal and State agencies. The letter shall include a description of the deficiencies, the urgency of the needed repair, and the nature of the deficiencies. Further, the letter will require the owner to submit a proposed maintenance schedule, and certify by letter, the completion of the required repairs.

Any dam having deficiencies that seriously effect the integrity of the structure must be promptly repaired or be removed from service until repairs are made (NFS DRAFT 7554.22).

Dams Not Under NFS Jurisdiction

When a dam is not on NFS lands or is under the jurisdiction of another agency, and conditions that endanger NFS lands is noted, the owner or agencies should be promptly notified (NFS Draft 7554.23).

SAFETY INSPECTION AND HAZARD ASSESSMENT

The effort and degree of detail involved for the safety inspection increases as the structure size and hazard classification increases (NFS Draft 7554.3).

Inspection and Hazard Assessment Schedule

A schedule for safety inspection or hazard classification review will be developed for each dam. The time interval for such inspection and review will not exceed 5 years for high hazard dams, 5 years for moderate hazard dams, and 10 years for low hazard dams.

The National Forest Service (NFS) is responsible for all Forest Service owned dams. The inspection of NFS dams may be subcontracted to responsible, qualified individuals or engineers. Qualified individuals, people chosen by the Forest Service who by reason of training and experience, are assigned by the Forest Supervisor or the Regional Forester to perform certain technical functions within the authorizing Officer's delegated authority (NFS Draft 7505.2).

The authorized special use permit holder is responsible for having safety inspections performed by a qualified engineer at the frequency prescribed in the permit (NFS Draft 7554.31).

Report Review and Approval

The Regional Director of Engineering of the NFS is responsible for review and approval of safety inspection reports (NFS Draft 7554.32).

EMERGENCY ACTION PLANS

Emergency action plans are required for all high hazard dams. Emergency plans will include maps of areas that would be inundated by waters, if the dam were to fail. Design stage emergency action plans are required. The emergency action plan should reflect the construction of new dams and the reconstruction of old dams (NFS Draft 7555).

Special Use Permits

Authorized special use permit holders are responsible for preparing an emergency action plan that meets with NFS approval (NFS Draft 7555.2).

Structural Failure Report

When a structure fails, prompt investigation and reporting is required.

Federal Lands Policy and Management Act Regulations

The Federal Lands Policy and Management Act (FLMPA) regulates Federal lands. Lands under the jurisdiction of the NFS are Federal lands, and are subject to FLPMA regulation. It is interesting to note that the same provisions apply to NFS lands as the BLM lands. The rental of right-of-way, land exchange, withdrawals, and rate schedules discussed in the section on the BLM apply to NFS lands. The NFS rates are not the same as the BLM, and will not be included here. An example would be, an entity is expected to pay more for the removal of salvageable material at a NFS site, where trees are involved, than a BLM site, where sage brush is involved.

INTERSTATE WATER COMPACTS AND COURT DECREES

Interstate compacts basically provide for the distribution and use of the waters of the rivers and streams that flow across State lines. These water are divided by two methods. One is by consumptive use, and the other is by division of divertible flow (Christopulos, 1982).

GENERAL

The interstate water compacts provide for the unlimited use of stock and domestic water ponds. These ponds and their water uses are defined explicitly in some of the compacts, but are not defined in others. For instance, in the Yellowstone River Compact, the definition of stock/domestic ponds states the acreage of gardens irrigated shall not exceed 1 acre. In all cases the limitation of 20 acre-feet is imposed on all stock/domestic impoundments. This limitation places no constraint on the height of the dam, only the use and the amount of the water retained. These stock/domestic water impoundments do not result in a deduction to the allocation provided for in the compacts.

The compacts also allow downstream States to build reservoirs in upstream States to impound water for use in the downstream State. When the downstream State exercises this right of eminent domain, restitution must be made to the upper State for the lands inundated. The lower State is also required to allow the upper State to pay for a portion of the construction cost equal in proportion to the upper State's apportionment, and thereby acquire a storage right in the reservoir.

Upstream States in general may not engage in diversions that deprive a lower State of its right to use the water regulated in the compacts. Out of basin diversions are permitted, but require unanimous commission consent in the Yellowstone and Snake River Compacts.

These are some of the generalities of the compacts. The peculiarities of the compacts will be presented below.

Bear River Compact 1978

The Bear River Compact divides the river into three sections: the Upper Division, the Central Division and the Lower Division. The compact allows Wyoming the right to divert certain percentages of divertible flow depending on the river section. Those sections and the percent of the appropriation are shown below.

1. Upper Wyoming Section Diversion . . . 49.3%
2. Lower Wyoming Section Diversion . . . 9.6%

These percentages of divertible flow are subject to the condition that a water emergency does not exist. A water emergency exists for the Upper Division when divertible flow is less than 1,250 cfs (ARTICLE IV(1)), and for the Lower Division, when divertible flow at the Utah-Idaho line is insufficient to satisfy the needs of Utah (ARTICLE IV(3)).

The Bear River Compact provides for storage rights in addition to the 2150 acre-feet Wyoming had before the compact. This additional storage is 35,500 acre-feet per annum above Stewart Dam, one half for use in Wyoming (ARTICLE VI(A)). This additional storage right is subordinate to existing storage above Stewart Dam and direct flow rights for consumptive use in any river division. Though this additional storage right is not subordinate to Bear Lake storage rights, Bear Lake level still controls new storage above Stewart Dam. As new reservoir storage above Stewart Dam is constructed to provide additional storage as indicated above, additional reserve irrigation storage will be provided in Bear Lake that equals the storage provided above Stewart Dam. The Bear River Compact illustrates Bear Lake stage versus storage. Table 4 is a replication of the compact's Stage versus Storage relationship.

Table 4. Bear Lake Stage Versus Storage

Additional Storage acre-feet	Lake Surface Elevation Utah Power and Light Company Bear Lake Datum
5,000	5913.24
10,000	5913.56
15,000	5913.87
20,000	5914.15
25,000	5914.41
30,000	5914.61
35,000	5914.69
36,500	5914.70

Because additional irrigation storage in Bear Lake, required as additional storage above Stewart Dam is provided, has not been achievable, Bear Lake is controlling the storage above Stewart Dam. Reserve irrigation storage in Bear Lake - the waters below the Utah Power and Light datum of 5912.91 feet above sea level - has been seriously depleted by existing rights in the area below Bear Lake (ARTICLE VI, D). These rights are not subordinate to the additional storage above Stewart Dam, and are dependent on Bear Lake's level. Therefore, until Bear Lake is at a level of 5912.91, and all existing water rights are being met, Bear Lake will dictate the construction of storage facilities above Stewart Dam.

Also, Wyoming, Idaho and Utah have the right to store and use water above Stewart Dam that would otherwise be bypassed or released from Bear Lake, when all other direct flow and storage rights are met (ARTICLE VI(C)).

This compact also has a provision for out of basin replacement water, of like quality, to be placed into the Bear River Drainage, and to be removed at a downstream location (ARTICLE IX).

Belle Fourché 1943

The Belle Fourché Compact is a compact between the States of South Dakota and Wyoming to regulate the beneficial use of the waters of the Belle Fourché River. The Belle Fourché Compact has a limitation of 1000 acre-feet on any new reservoirs built in the Belle Fourché drainage (ARTICLE IX). Unappropriated waters will be allocated with Wyoming receiving 10%. Either State has the right to the other's unused water appropriation, but this use does not confer a right to the water (ARTICLE V).

Colorado River Compact 1922

This compact divides the Colorado River Basin into two regions: the Upper Region, of which Wyoming is a part, and the Lower Region. The Upper Region is entitled to 7,500,000 acre-feet per year, inclusive of existing rights (ARTICLE III(a)). This water is subject to the restriction that the flow at Lee Ferry, AZ is to be maintained at

75,000,000 acre-feet for 10 consecutive year periods (ARTICLE III(c)). Any water impounded for power generation is subordinate to agricultural and domestic use (ARTICLE IV(b)).

Upper Colorado River Basin Compact 1948

This compact apportions waters of the Upper Basin to the States of the Upper Basin: Utah, Colorado, New Mexico, Wyoming, and Arizona. These waters were initially allocated to the Upper Basin by the Colorado River Compact 1922. This compact also contains regulations on two tributaries: the Little Snake River and the Henry's Fork.

The apportionment of the Upper Basin water allows Arizona 50,000 acre-feet and the remaining States a portion of what remains. Wyoming's portion of the remaining water is 14% (ARTICLE III(a)(2)).

If a reservoir is constructed to aid Upper Division States in making their quotas at Lee Ferry, reservoir losses are chargeable to the benefiting States' allotments in the same proportion as the allotments (ARTICLE V(b)(1)). If a reservoir is constructed by a State for the use of the State the losses will be charged to that State's allotment.

Little Snake River

The water diverted from any tributary of the Little Snake River or from the main stem of the Little Snake above a point 100 feet below the confluence of the Little Snake River and Savery Creek shall be administered without regards to rights covering the diversion of water from any down-stream points (ARTICLE XI(a)(1)). Water diverted below the point mentioned above will be administered with the basis of priority schedule prepared by the Commission (ARTICLE XI(a)(2)). The States of Wyoming and Colorado each consent to diversions and storage of water in one State for use in the other State (ARTICLE XI(d)). Waters of the Little Snake River shall be developed for full use, without regard to State line, but should result in as nearly equal division between the States of Colorado and Wyoming as practical. Consumptive use of the water shall be charged to the State where the use is made. This charge will go against that State's Colorado River Compact 1922 allotment (ARTICLE XI(f)).

Wyoming still has unused water allotments in the Colorado River drainage in the Green River and its tributaries. This water may be diverted out of the basin as was done in the Cheyenne Stage II water project. The States of the Lower Basin have been using this unused portion for many years, especially the State of California (National Geographic, June 91). Presently, discussions on the use of water by the lower basin states is occurring to rectify problems which may arise in the future when most states are utilizing their allocations.

Henrys Fork

Waters of the Henrys Fork and its tributaries will be administered without regard to State line on the basis of an interstate priority schedule prepared by the States effected. This schedule is subject to the Colorado River Compact Commission's approval, and must conform to the actual priority of right of use (ARTICLE XII(a)). Water uses initiated after the signing of this compact will be divided on a 50-50 basis.

Snake River Compact 1949

The waters of the Snake River are apportioned to the States of Wyoming and Idaho, with Wyoming receiving 4% of the divertible flow at the Wyoming-Idaho State line. This apportionment is after existing rights are met (ARTICLE III). Of this 4%, one-half may be used for direct diversion or storage without providing for replacement storage space. The second half may be diverted for direct use or storage provided Idaho is reimbursed with replacement storage of one-third the second half, or 2/3% (ARTICLE III(1)&(2)). Replacement storage has been provided through the use of reservoir storage in Palisades Reservoir of which Wyoming is a storage holder. Therefore, this should no longer be an issue in this compact

(John Shields, WSEO, Friday August 1,1991).

No water may be diverted by Wyoming out of basin without the approval of Idaho. No water of the Salt River drainage may be diverted out of basin for use in Idaho without the approval of Wyoming (ARTICLE IV).

Upper Niobrara River Compact 1962

The Upper Niobrara River Compact restricts surface water usage on the main stem of the Niobrara River east of Range 62 West of the 6^{th} P.M. and from the main stem of Van Tassel Creek south of Section 27, Township 32 North, Range 60 West of the 6th P.M. for rights acquired on different dates in different ways.

For reservoirs constructed after August 1, 1957, 500 acre-feet is the maximum allowable storage for any water year (October 1 through September 30).

For storage in reservoirs built after August 1, 1957, diversions for storage shall be made only from October 1 of one year to May 1 of the next year, and at such times during the May 1 to August 1 period that the water is not needed for other uses and diversions in Wyoming and Nebraska (ARTICLE V). All other surface waters of the Upper Niobrara drainage are not restricted (ARTICLE V).

Yellowstone River Compact 1950

The Yellowstone River Compact provides for the division of waters of the Yellowstone River and its tributaries. Existing rights will maintain their diversion rights from May 1 to September 30. All unappropriated or unused divertible flow will be allotted to Wyoming and Montana on a percentage basis. No out of basin diversions are allowed without the unanimous consent of the Yellowstone River Compact Commission (ARTICLE X).

Wyoming's Allotments

The proportion of unallocated water available for Wyoming use after prior rights are met are shown below by tributary.

Clarks Fork	60%
Bighorn River	80%
Tongue River	40%
Powder River	42%

The amount of water available for diversion is calculated by a hydrologic budget formula (ARTICLE V(C)). All existing water rights are honored.

Devices and facilities for the control and regulation of surface waters are excluded from the provisions of this compact (ARTICLE V(E)(2)). This indicates that, if an allotment of water were properly secured, no restrictions on impoundment would exist in this Compact.

Laramie River Court Decree 1957

The Laramie River Court Decree is the latest of a long line of Supreme Court settled disputes between the States of Wyoming and Colorado over the use of the waters of the Big Laramie River. Basically, Colorado has sought to increase its allotment for in basin use and transmountain diversion (out of basin use), while Wyoming has sought to maintain the existing flow across the State line.

Today, Wyoming has available, what remains after Colorado exercises its usage of the allotments provided by the Supreme Court ruling. This Colorado allotment consists of 19,875 acre-feet for out of basin diversion, and 29,500 acre-feet for meadowland use within the basin, but no more than 1,800 acre-feet may be diverted after August 1 in any water year. Any of the 19,875 acre-feet not diverted out of basin may be applied to meadowland irrigation within the basin. The relative rights of the users will be preserved in the decree.

Nothing is discussed with regard to storage in the decree, but as a tributary to the North Platte, North Platte River regulations may have jurisdiction. Since the Laramie River's confluence with the North Platte River lies below Guernsey, WY, impoundments would not be restricted by the North Platte River Court Decree, but Wyoming would have only 25% of the divertible flow.

North Platte River 1945

The Supreme Court has been called upon many times to settle disputes between the States of Wyoming, Colorado and Nebraska regarding water usage of the North Platte River. The present status of the usage varies depending on the river section.

The Section of the River below Guernsey Reservoir is apportioned to the States of Wyoming and Nebraska, with 25% belonging to Wyoming and 75% belonging to Nebraska. The apportionment is with regards to the natural flow of the river in this section. Also in this section, the yield of a reservoir at Glendo (40,000 acre-feet/annum) is apportioned, with Wyoming receiving 15,000 acre-feet and Nebraska receiving 25,000 acre-feet on an annual basis. This decree requires that the operation of Glendo reservoir will not impair upstream water usage and availability.

The section above Guernsey Reservoir is also regulated by this decree. Wyoming has the right to permit the diversion of water to irrigate 168,000 acres of land per irrigation season. This diversion is exclusive of Kendrick Project Allotments. The decree specifies this diversion restriction applies to the main stem of the North Platte River from Guernsey Dam to Pathfinder Dam, and from the North Platte and its tributaries above Pathfinder Dam.

This decree restricts storage above Pathfinder Dam to 18,000 acre-feet in any water year. This restriction applies to the main stem of the North Platte River and its tributaries above Pathfinder Dam. A stockwater\domestic use exclusion is stated in this decree, but a size criteria is not specified.

SUMMARY

These Interstate Water Compacts and Court Decrees can effect what is permitted for storage and how the storage is used. Most of the compacts and the North Platte River Supreme Court decision allow the unlimited use of stockwater/domestic use reservoirs without reduction of the allotment provided in the compact or decree. Beyond this exemption, the storage amounts are set by the amount of the allotment left after prior rights are met. The right to fill in order of priority exists for all compacts and decrees.

The restrictions are noted, but in summary the Belle Fourché has a limitation on reservoirs size; the Niobrara has restriction on when reservoirs can be filled and how much may be stored per water year; the Bear River has limitations on storage and rules for filling; the Colorado has restrictions on allotments available to Wyoming for use as does the Snake River and Yellowstone River.

The only Compacts that restrict out of basin diversions are the Snake and the Yellowstone River Compacts. The Laramie River Decree and the North Platte River Decree regulate the amount of out of basin diversion allowed.

Wyoming State Engineer's Office

General

A Surface Water (S.W.) permit is required before commencing construction of any dam or reservoir involving the storage or impoundment of water in Wyoming (Part I, Chapter V, Section 1(a)). Maps and plans must be submitted for a permit to construct any dam. These maps, plans and applications are to be prepared by a Licensed Surveyor or Professional Engineer, except when those dams are covered by Special Provisions of the Wyoming State Engineer for stockwater, fishing preserve, and flood detention reservoirs. The Special Application requires a less complicated application procedure, and will be discussed next (Chapter V, Section 1, Wyoming Surface Water Regulations).

Special Permit Reservoirs

Dams that are less than 20 feet in height and less than 50 acre-feet in capacity may qualify for a Special Permitting process set forth by the Wyoming State Engineer, if they serve as stock water, fishing preserve, or flood detention impoundments (Part I, Chapter V, Section 1(a)). This form relieves the permittee of the burden of employing a Registered Professional Engineer or Licensed Surveyor to prepare maps and plans, and file applications for the dam and reservoir. This Special Permit allows the permittee to perform the functions of the engineer, and to provide the Wyoming State Engineer with the required information for the application process. Some of those requirements are provided in Table 5 shown below. The forms for these Special Permit Reservoirs are;

1. S.W. 1 for the appropriation of surface water,
2. S.W. 4 for stock water reservoirs,
3. and form S.W. 3 for fishing preserve reservoirs, and flood detention reservoirs. This S.W. 3 Application Form is the Regular Reservoir Permit Application (Part I, Chapter V, Section I(b)).

These reservoirs are to be used for the use specified in the Special Permit Application, and may not be used for irrigation (Studley and Benner).

Table 5. Wyoming State Engineer's Special Permit Requirements

ITEM	REGULATIONS	COMMENTS
Drawings		
Cross Section Drawings	Profile along center line and maximum cross section of dam.	This drawing should include sufficient engineering detail of the dam cross section.
Outlet Works and Spillway	Spillway and Outlet works in detail, with capacity computations shown. Flood detention ponds are required to have an 18 inch outlet pipe.	Material and capacity details should be provided with the drawings of the outlet works and spillway, so the Wyoming State Engineer's office can determine the adequacy of the design.
Scale	1"=400' reservoir contour maps. 1"=1000' for reservoir basins with widths or lengths of 2 miles if detail can be shown. 1"=200' for reservoir profiles 1"=20' for cross section plans 1"=4" for detailed plans including outlet works 2"=1 mile is the minimum acceptable USGS quadrangle scale. 4"=1 mile is the minimum acceptable aerial photo scale.	Should be large enough to clearly show the design detail. These are suggested ranges. The location and area maps are not required if the application is accompanied by United States Geological Survey USGS quadrangle maps or aerial photographs.

Table 5 (Continued)

ITEM	REGULATIONS	COMMENTS
Dimensions For Earth dams	3 to 1 for the front or water side 2 to 1 for the back side Top width=.2(Height)+4 Freeboard of the spillway is 5 feet	Dam height (Height) is measured from the downstream toe to the top of the embankment.
Spillway Design Flow	None for low hazard dams	The 100 year storm event comes into play at 20 feet of height.
Wyoming State Engineer's Exceptions	The Wyoming State Engineer may require more stringent detail and design when it is deemed appropriate.	The Wyoming State Engineer may require detailed construction plans and engineering mapping when he finds it to be necessary.
Capacity Table	Capacity of the different filling levels will accompany the map.	Filing requires that the level and the capacity be shown in a table. The formula used for this calculation is 1/3 average depth times the area.
Maps	Location and area maps are required when USGS and aerial photographs are not provided.	Location maps indicate the proper subdivision of the reservoir, and the area maps indicate the proper dimensions of the storage facility.

Table 5 (Continued)

ITEM	REGULATIONS	COMMENTS
Dimensions	Shown on the area map	Show the area of the reservoir, the capacity of the reservoir, the profile of the dam and the cross sectional view of the dam. The capacity and spatial extent will be calculated with the water level at the high water line. The outlet pipe and spillway cross section will be shown on the area map with their locations. Elevations of the high water line, the lowest point of the reservoir, the top of the dam, the base of the spillway, and outlet invert will be shown on the map. North arrow and scale must be shown.
Enlargements	Capacity table of the reservoir before and after the enlargement is shown.	
Priority Filling	The reservoir will be filled in priority from the stream or supply ditch	

The requirements shown in Table 5 were derived from Chapter V, Section I(b), of Part I of the Wyoming Surface Water Laws, and are the basic requirements for Special Application procedures of the Wyoming State Engineer.

Reservoir permits do not imply any right to divert water to store in a reservoir, only the right to construct and store water. Form S.W. 1 should be filed to acquire the water right to fill an impoundment when applicable.

Construction Design and Materials

The basic small dam construction, design, and material requirements specified by the Wyoming State Engineer are those specified in the SCS publication, Pond. This publication is discussed later in the thesis.

Off-Channel Reservoirs

An important part of this thesis is the feasibility of off-channel storage. The regulations concerning this type of storage should include all the structural and H&H (hydraulic and hydrologic) specifications required of any dam; the differences in the permitting result from additional supply source permit requirements. Reservoir permit S.W. 3 allows for the impoundment and use of water in the stream specified in the permit. If an off-channel facility is desired, additional permits for the supply facility will be required (Part I, Chapter V, Section 2).

These additional requirements for off-channel storage include a S.W. 1 form be filed to obtain the right of the supply, or a S.W. 3 be filed if the use of an existing supply facility is to be expanded for the new storage facility (Part I, Chapter V, Section 3). These forms require that the new use be specified, and that the new use's supply location be shown on a location map. The cross section of the supply ditch and the supply ditch hydraulic characteristics must be shown on the location map, along with the location and extent of the lands to be irrigated. The requirements or a capacity table and location of the outlet by section tie are the same as specified above in Table 5. Basically, off-channel storage requires that the supply channel be permitted in addition to the reservoir permit.

INTERAGENCY REQUIREMENTS

It should be noted that the Wyoming State Engineer does not require the advisement of the USCE through its application process, except when the lands effected are not State or private lands. When the lands effected are Federal Lands the permit requires that those lands be listed, and the appropriate agencies be notified.

On the other hand, when the USCE is notified of a permit to Dredge and Fill, the USCE through a Memo of Understanding (MOU) does require the Wyoming Department of Environmental Quality (WDEQ) be notified. The WDEQ will notify the Wyoming State Engineer though its normal operating procedures.

SAFETY OF DAMS

The Safety of Dams Program developed by the Wyoming State Engineer's office is similar to the USCE inventory and inspection of dams program except for a minor detail. If the 20 feet height, the upper limit of height before it is mandatory that the State periodically inspect the dam, does not include a freeboard of 5 feet, then the regulations are essentially the same. This was not found to be the case, however. The Wyoming State Engineer defines the height of a dam as the distance from the downstream toe to the top of the dam. The periodic inspection time interval is 5 years. The 50 acre-feet storage maximum is also used, along with the height limit, for mandatory inspection (WS 41-3-307).

The State Safety of Dams Program also incorporates many of the USCE's ideas into its program, most notably liability disclaimers and emergency breaching requirements. The liability issue exempts the State from damages and repair costs when a dam fails, or when emergency breaching is required for the Public Safety (WS 41-3-313(b)). The program places the cost of breaching with the owner of the structure, and provides for the placement of liens against the owner's property to insure reimbursement.

Another aspect of emergency breaching is that it should only be required in the case of dams constructed before the program's initiation. Dams constructed after this date are required to be constructed with an outlet system with a headgate, that is maintained in proper working order, allowing for water evacuation at any time (WS 41-3-313(a)).

The Safety of Dams Program may be expanded to include the inspection of structures under the 20 foot height limit, if the Wyoming State Engineer feels it is appropriate because of risk factors, such as proximity to inhabited or developed areas (WS 41-3-316).

An effort is underway to revamp the Wyoming State Engineer's Safety of Dams Act and align it with the Safety of Dams provisions of 33 CFR 220. The definition dam height will be a difference if not changed from the distance from downstream toe to the top of dam, which is the WSEO definition, to the distance from the downstream toe to the crest of the unregulated emergency spillway, which is the USCE's definition. The minimum criteria for inspection of six (6) feet dam height or fifteen (15) acre-feet storage capacity will be adopted as the lower levels of dam inventory and inspection. Other refinements, such as a 25 feet mandatory inventory and inspection height criteria similar to the USCE's may also result. The draft of this new program was on the State Engineer's desk at the time of this writing, and was not available for this thesis. The draft is not expected to be in a releasable form until, December, 1992 (Benner and Studley, WSEO, July 91).

INDUSTRIAL DEVELOPMENT AND SITING ACT

The Industrial Siting rules and regulation become important when an "Industrial Facility" has an estimated cost of 112 million dollars ($112,000,000). It is unlikely that projects of this size will come under the jurisdiction of the Industrial Siting Commission. Deer Creek, a much larger reservoir than the proposed small storage projects, has projected costs of 55 million dollars ($55,000,000), and is the large facility that, in part, prompted this feasibility study. Therefore, it is unlikely that the small storage project, either individually or cumulatively will be subject to Industrial Siting Regulations.

STATE FORESTER

The State's forests are under the regulation of the State Forester, who is under the jurisdiction of the Wyoming Public Lands Commission (WPLC). This State Agency operates much the same as the BLM does except that the easements and leases are sold to the applicants and not rented as is the case for the Federal Agency. These purchased easements and leases are titled to the holder for the life of the holder's project. When the project has outlived its usefulness the lands revert back to State ownership, and the title, once again, belongs to the State. There is very little difference from renting as the BLM does for easements and leases. The only difference is the transfer of title.

Like the BLM's right-of-way processes, the State's land sales are subject to conditions. If these conditions are obeyed, the lands will remain in the hands of the holder for their use; if not, the lands may be removed from the holders use.

USDA - SCS POND (378)

PURPOSE

Ponds specified by SCS POND (378) are constructed for livestock, fish, wildlife, recreation, fire control, crop and orchard spraying and other related uses. This publication is the foundation for the design criteria of small dams for the State of Wyoming, the National Forest Service, and the USDA-SCS. These specifications are for dams less than 35 feet in effective height, and are contained in condensed form in the pages that follow.

Scope

This standard establishes the minimum acceptable quality for the design and construction of ponds in rural areas under the jurisdiction of the USDA-SCS.

Effective Height

The effective height of a dam is the height from the downstream toe to the lowest point on the center line of the dam, presumably the emergency spillway where equipped.

Hazard Class A

The upper limit of a Hazard Class A dam is less than or equal to 35 feet effective height. This is a height chosen by the SCS to define lower hazards in predominantly rural areas. These dams of Hazard Class A are the same as the USCE low hazard class and the NFS low hazard class, and the same requirement for no loss of life if the structure fails is in effect. The SCS also specifies a quantity of the effective height times the storage capacity at the high water line be less than 3000 acre-feet squared to be considered a Hazard Class A structure. This criteria must be met to qualify a dam for construction under the POND criteria. If the 35 feet is what the NFS defines as the hydraulic dam height, the 35 foot SCS dam would be the same as the 40 feet administrative NFS dam height with 5 feet of freeboard. The SCS has many regulations for the construction of dams under its authority. These will be covered in the following paragraphs.

Conditions Where Practice Applies

Site Conditions

Runoff from a design storm must be passable by:

1. Emergency Spillway, or
2. Combination of emergency spillway and principal spillway, or
3. A principal spillway.

Drainage Area

The drainage area above the pond shall be large enough that surface runoff along with any groundwater flow will maintain an adequate supply of good quality water for the pond. The drainage area of the pond will have ground cover that eliminates excess sedimentation which reduces the useful life of the pond.

Depth

A minimum depth of eight (8) feet is required, except when a lesser depth is approved by an engineer.

Foundation

The foundation material should have a shear strength capable of supporting the dam without excessive consolidation. The foundation material shall have a low hydraulic conductivity to prevent excessive seepage.

Reservoir Area

Soils in the reservoir area shall be of the low infiltration type when surface runoff is the predominate source of reservoir supply, or the soils shall be sealable.

Range Planning Requirements for Stock Water Developments

The development must:

1. Facilitate proper range use by distribution of grazing,
2. Meet the water distribution requirements of livestock, and
3. Be the most feasible method of development of the needed water supply

The distribution of stock watering ponds shall be such that the stock need not travel more than one mile or less than one half mile from forage to water on gentle relief. On rough relief, the greatest travel distance from forage to water should not exceed one-half mile nor be less than one-quarter mile. Stock water ponds should not be planned at closer intervals than these.

Design Criteria - Embankment Ponds

Embankment Ponds

An embankment pond is an impoundment formed by the construction of a dam or embankment.

Reservoir Storage

Storage requirements will be determined by the proposed use of the pond. Losses due to evaporation and seepage and allowances for sediment storage must be considered.

Foundation Preparation

Design of embankments shall include provisions for bonding the embankment material with the surface material of the foundation in a manner that will prevent excessive water passage at the line of contact and excessive embankment settlement. This will include all necessary grubbing, stripping, clearing and shaping.

Design of earth embankment dams shall include a treatment of the natural foundation which will provide, reasonable assurance, that excessive or dangerous seepage will not occur. Selected treatment will be based on the information in Table 6.

Table 6. SCS Foundation Requirements

Category	Specification
Foundations of deep(3.0+ft) soil subject to surface cracking.	Minimum Cutoff Trench - 4.0 ft deep after stripping.
Foundations for dams consisting of deep(3.0+ft) relatively impervious soil and having shallow rooted vegetation.	Minimum Cutoff Trench - 2.0 ft
Foundations containing willow, tree, or sagebrush growth.	Minimum Cutoff Trench - 2.0 ft deep after stripping and grubbing.
Foundations containing a pervious surface layer underlain by relatively impervious material in the first 5 feet of depth.	Minimum Cutoff Trench - extending 1 ft into the impervious material.
Foundation for dams containing a relatively impervious surface layer at least 2 ft thick underlain by a pervious but stable material and having shallow rooted vegetation.	Minimum Cutoff Trench - 2.0 ft after stripping, and consider the need for a foundation drain.
Foundation conditions which cannot be compared to any of the above items.	Special investigation made by geologist or engineer and coring recommendations followed.

Minimum bottom width of cutoff trenches shall be 8 feet with a maximum side slope of one to one. Rock foundations require special consideration due to jointing, weathering, etc.

Seepage control is to be included if:

1. Pervious layers are not intercepted by the cutoff,
2. Seepage may create swamping downstream,
3. It is needed to insure a stable embankment, or
4. Special problems require drainage for a stable dam.

Seepage control may be accomplished by:

1. Foundation, abutment or embankment drains,
2. Reservoir blanketing, or
3. A combination of these methods.

EARTH EMBANKMENT

Embankment design will be based on site and foundation characteristics. Consideration will be given to foundation settlement, differential settlement in the foundation and abutments, fill material - plasticity and imperviousness, foundation drains, toe drains, embankment stability, berms, compaction requirements, special moisture requirements, and other appropriate site and design conditions. In the more complex jobs, fill and foundation material may have to be sent to a Soils Laboratory for testing.

Top widths are shown in Table 7, but the minimum top width for a dam with a one way road is 16 feet and for a dam with a two way road is 26 feet. A guardrail will be installed whenever the height of the embankment exceeds 10 feet. For this standard the maximum effective height is 35 feet.

Table 7. SCS Top Width Requirements

Total Height of the Embankment (feet)	Top Width (feet)
10 or less	6
11 - 14	8
15 - 19	10
20 - 24	12
25 - 34	14
35 - up	15

Side slopes on the upstream face will not be steeper than 3 to 1, and on the downstream face not steeper than 2 to 1. Flatter slopes may be necessary to assure slope stability for certain materials.

Settlement allowances will be made by increasing the as constructed dam height to allow for settlement. This dam height increase for settlement allowance will not be less than 5 percent of the designed dam height or more than 10 percent of the designed dam height. This range may be altered where detailed soils testing shows that other amounts are adequate.

The face of the dam will be protected against wave erosion by berms, riprap, sand-gravel, soil cement, or special vegetative cover.

PRINCIPAL SPILLWAY

A principal spillway with needed appurtenances shall be installed in a dam to protect the earth emergency spillway when, because of site limitations, the emergency spillway must be located in an erosive soil and safe velocities cannot be maintained for a reasonable distance below the control section. A reasonable distance is defined as that distance necessary to insure that flows ranging from annual peak to maximum design peak will not seriously breach the emergency spillway during an 8 to 10 year period.

The minimum capacity of the principal spillway before an emergency spillway operation shall equal the peak outflowrate as determined by the following formula and considering the reservoir is 70 percent empty:

$$Q_o = Q_i\ (1 - \text{Square root}(V_s/V_f))$$

Where:

V_s = Estimated volume of 70 percent (or less) of reservoir capacity in acre-feet
V_f = Total runoff from a 2 year, 6 hour storm in acre-feet.
Q_i = Inflow peak rate of a 2 year, 6 hour storm in cfs.
Q_o = Minimum required capacity of principal spillway in cfs.

If this method of determining minimum capacity of a principal spillway results in zero flow, no principal spillway is required. However, when low sustained trickle flows occur, principal spillway will be required to handle such flows.

For conduit spillways a minimum diameter of 12 inches will be required for the principal spillway, when the function of the principal spillway is to discharge floodflows. When the function of the principal spillway is to discharge trickle flows, the minimum diameter of the barrel shall be 8 inches. The minimum diameter of the riser on drop inlets shall be 1.25 times the diameter of the barrel, but not less than 12 inches.

Hydraulic Design of Conduit Spillways

The riser and barrel for drop inlets shall be designed to provide full pipe flow after weir flow is exceeded. Design shall be based on the Engineering Field Manual, or other suitable tables.

When design discharge of the principal spillway is considered in the emergency spillway routing, the elevation of the principal spillway inlet will be such that full pipe flow occurs before the emergency spillway is entered. The crest of the principal spillway inlet will be .5 feet below the crest of the emergency spillway for drop inlet risers. The invert of hood inlets will be located 1.8 times the diameter below the crest of the emergency spillway.

The barrel of the outlet may be combined with the barrel of the principal spillway, providing flow requirements can be met.

PIPE CONDUIT MATERIALS

Pipes shall be capable of withstanding external loading without yielding, buckling, or cracking. Pipe strength is not to be less than that of grades indicated in Table 8 for plastic pipe, and Table 9 for corrugated aluminum and galvanized steel pipe. Inlets and outlets are to be structurally sound and made of compatible materials that are sealed against leakage with gaskets, caulking or welding.

Table 8. Maximum Depth of Fill for Plastic Pipe* Schedule

Nominal Pipe Size (inches)	Schedule for Standard Dimension Ratio (SDR)	Maximum Depth of Fill Over Pipe (feet)
4 or smaller	Schedule 40 Schedule 80 SDR 26	15 20 10
6, 8, 10, 12	Schedule 40 Schedule 80 SDR 26	10 15 10

* Polyvinyl Chloride Pipe, PVC 1120 or PVC 1220, conforming to ASTM D-1785 or ASTM D-2241

Table 9. Minimum Gage Requirements

Fill Height Above Pipe (feet)	2 - 2/3 inch X 1/2 inch Corrugations*									
	Steel - Minimum Gage						Aluminum Minimum Thickness (inches)			
	Pipe Diameter in Inches						Pipe Diameter in Inches			
	<=21	24	30	36	42	48	<=21	24	30	36
1 - 15	16	16	16	14	12	10	.06	.06	075	.075
15 - 20	16	16	16	14	12	10	.06	.075	.075	.075
20 - 25	16	14	14	12	10	10	.06	.105	.135	xx
	All Dams Over 20 feet Effective Height									
Up to 25	16	14	12	10	8	8	xx	xx	xx	xx
	3 inch X 1 inch Corrugations*									
0 - 20	16		16			16				
20 - 25	16		16			14				

* Riveted or helical fabricated.
xx Not permitted.

For dams less than 20 feet in effective height, the following materials are acceptable: cast iron, steel, corrugated steel or aluminum, asbestos - cement, concrete, plastic, vitrified clay with rubber gaskets and cast-in-place reinforced concrete. Asbestos - cement, concrete, or vitrified clay shall be laid in a concrete bedding. Plastic pipe that will be exposed to sunlight shall be made of Ultraviolet (UV) resistant plastic, protected by coatings or shielding, or provisions must be made for replacement as necessary. Connections of plastic pipe to less flexible pipe or structures must be designed to avoid stress concentrations that could rupture the plastic.

For dams more than 20 feet in effective height, conduits are to be reinforced concrete pipe, cast in place reinforced concrete, corrugated steel or welded steel pipe. The maximum height of fill over steel pipe shall not exceed 25 feet. All pipes are to be water tight, and the joints of the pipe shall remain water tight after soil loading and consolidation which causes joint elongation. Concrete pipe shall have concrete bedding or a concrete cradle if required. Cantilever outlet sections shall be designed to withstand the cantilever loading of the water and dead load, and pipe supports shall be provided when required. Cathodic protection shall be provided for galvanized pipe where soil resistivity is less than 4,000 ohms-cm or when the pH is lower than 5. Engineering Practice Standard 432-F should be used to determine cathodic protection requirements for welded steel pipe, and may be obtained from the SCS.

Aluminum corrugated metal pipe (CMP) is restricted to soils with a pH range of 4 to 9, and excluded from soils where excessive deterioration of aluminum is known to occur. The maximum diameter of aluminum CMP used for principal spillway barrels is 36 inches, and the maximum positive or negative gage pressure is 15 feet of head of water. Coupling bands and antiseep collars must be made of the same material as the pipe barrel. If gates or other fittings are to be made of material other than aluminum or if aluminized steel is to be used with aluminum pipe, the materials are to be separated by at least two (2) layers of plastic tape or 24 mils. Bolts other than aluminum are to be galvanized or plastic coated.

ANTISEEP COLLARS

Antiseep collars are to be installed around the pipe conduit or pond drain in the normal saturation zone if any of the following conditions exist:

1. the settled height of the dam exceeds 15 feet,
2. the conduit is of smooth pipe larger than 8 inches in diameter, or
3. the conduit is of corrugated metal pipe larger than 12 inches in diameter.

The antiseep collars and their connections to the pipe shall be watertight. The collar material shall be compatible with the pipe materials. The maximum spacing shall be approximately 14 times the minimum projection of the collar measured perpendicular to the pipe. A two (2) feet projection is normal. The length of the seepage path through the impervious material shall be increased by a minimum of 15 percent. Minimum metal thicknesses shall be 16 gage. Refer to Section E of Technical Release No. 46.

ANTIVORTEX DEVICES

Closed conduit spillways designed for pressure flows are to have adequate antivortex devices.

TRASH GUARDS

Trash guards will be installed at the inlet or riser, when it is necessary to prevent clogging of the conduit.

PIPE SUPPORTS

Where cantilever outlets are used, structural supports will be used to support the outlet end of the pipe for pipe sizes above 18 inches. The need for structural support for sizes 18 inches or less will be determined from an evaluation of site conditions. The outlet end of the barrel will be placed a minimum of one (1) foot above the base grade of the channel below the dam and extend at least five (5) feet beyond the point where the downstream toe crosses the invert of the barrel.

EMERGENCY SPILLWAYS

Emergency spillways are provided to convey large flood flows safely past earth embankments. An emergency spillway must be provided for each dam, unless the principal spillway is large enough to pass the routed design hydrograph peak discharge with trash accumulation associated with the discharge without overtopping the dam. A closed conduit principal spillway having a conduit with a cross section area of three (3) square feet or more, an inlet which will not clog, and an elbow designed to facilitate the passage of the trash is the minimum size and design that may be utilized without an emergency spillway.

The minimum capacity of a natural or constructed emergency spillway shall be that required to pass the peak flow expected from a design storm of the frequency and duration shown on Table 10, less a reduction creditable to conduit discharge and detention storage.

Table 10. Minimum Design Storm Data

Drainage Area (acres)	Effective Height of Dam (feet)	Storage (acre-feet)	Minimum Design Storm	
			Frequency (years)	Duration (hours)
20 or less	20 or less	less than 50	10	24
20 or less	over 20	less than 50	25	24
over 20	20 or less	less than 50	25	24
All Others			50	24

The emergency spillway shall safely pass:

1. the peak flow, or
2. the storm routed through the reservoir

Routing

Routing will start with the water level of the reservoir at the crest of the principal spillway, or at the surface after a ten (10) day drawdown, whichever is higher. The ten day drawdown shall be computed from the crest of the emergency spillway or from the elevation that would be attained had the entire design storm been impounded, whichever is lower. Emergency spillways are to provide for passage of the design flow at a safe velocity to a point downstream where the dam will not be endangered.

Freeboard

Freeboard is the vertical distance between the water surface in the reservoir when the emergency spillway is discharging the routed or instantaneous peak flood flow and the top of the settled dam. The freeboard distance shall not be less than one and a half (1.5) feet.

FLOW DEPTHS AND VELOCITIES

Flow velocities will be such that the values in Table 11 for vegetated and Table 12 for earth spillways will not be exceeded. The values given in these tables will be used when the Field Engineering Manual (FEM) values are exceeded. Additionally, earth spillways will be designed to flow at a depth not exceeding two and one half (2.5) feet. These velocities must be maintained for a reasonable distance downstream from the dam.

Table 11. Permissible Velocities for Vegetated Earth Spillways

Type of Cover	Permitted Velocity		(feet per second)	
	Erosion Resistant Soils		Easily Erodible Soils	
	Slope of exit Channel (Percent)		Slope of exit Channel (Percent)	
	0 to 5	5 thru 10	0 to 5	5 thru 10
Bermuda Grass	8 fps	7 fps	6 fps	5 fps
Buffalo Grass Kentucky bluegrass Smooth brome Blue grama	7 fps	6 fps	5 fps	4 fps
Grass mixture	5 fps	4 fps	4 fps	3 fps
Lespedeza Weeping lovegrass Yellow bluestem Kudzu Alfalfa Crabgrass	3.5	DO NOT USE	2.5	DO NOT USE

Increase the values of Table 11 by 10 percent when the anticipated average use of the spillway is not more frequent than once in 50 years, or 25 percent when anticipated use is not more frequent than once in 100 years.

Table 12. Permissible Velocities for Earth Spillways

Original Material Excavated	Feet per Second
Fine sand, non-colloidal	1.50
Sandy loam, non-colloidal	1.75
Silt loam, non-colloidal	2.00
Alluvial silts, non-colloidal	2.00
Ordinary silts, non-colloidal	2.50
Volcanic ash	2.50
Fine gravel	2.50
Stiff clay, very colloidal	3.75
Graded, loam to cobbles, colloidal	3.75
Alluvial silts, colloidal	3.75
Graded, silt to cobbles, colloidal	4.00
Coarse gravel, non-colloidal	4.00
Cobbles and shingles	5.00
Shales and hardpans	6.00

Cross sections of earth and vegetated spillways shall be trapezoidal and will be located in undisturbed or compacted earth. The side slopes shall not be steeper than 1.5 to 1 in earth or loose rock. Side slopes in hard rock may be vertical. Vegetation shall be considered and used, wherever possible, to stabilize earth spillway side slopes and bottoms. The minimum bottom width for earth emergency spillways on dams with effective heights greater than 20 feet will be ten (10) feet.

The constructed spillways will have several component parts. The spillways will have an inlet section, and control section, and an exit channel. The inlet section will be level for a minimum distance of 20 feet upstream from the control section. Upstream from this level section the inlet section will have a reverse grade.

The grade of the exit channel shall permit the requirements of discharge velocity and depth to be met. The exit channel will terminate at a point far removed from the embankment, so as to protect the embankment from the erosive effects of the discharge. The exit channel should be straight to a point well removed from the back toe of the dam.

A wing dike or trail dike shall be provided if necessary to prevent spillway discharge from coming into contact with the back toe of the dam. The wing dike should have a top width of not less than eight (8) feet, and side slopes of not greater than 2 to 1. The upper portion of the wing dike is a level section, with a height equal to the height of the dam. The lower region of the dike will have the slope of the exit water level during the peak flood flow.

Natural spillways may be used if they are adequate in size, shape, and slope. Natural spillways must direct spillway flows away from the embankment.

Structural Emergency Spillways - Chutes or drops, when used for principal spillways or principal - emergency or emergency spillways will be designed in accordance with the principals set forth in the Field Engineering Manual (FEM) for Conservative Practices. The minimum capacity of a structural spillway shall be that required to pass the peak flow expected from a design storm of the frequency and duration shown in Table 10, less any reduction creditable to conduit discharge and detention storage.

OUTLET WORKS

A gated outlet will be provided where required by law or where there is a need to empty or lower the reservoir from time to time for proper pond management. When the reservoir stores more than 20 acre-feet, the minimum outlet size is 12 inches in diameter (Wyoming State Engineer Requirement). When the reservoir stores less than 20 acre-feet, the minimum size shall be four (4) inches in diameter. Small diameter supply pipes will have a minimum inside diameter of one and a quarter (1.25) inches.

Capacity of the outlet, sizes and release rates may be restricted at certain locations by the Wyoming State Engineer. It is the responsibility of the owner to discover if any special requirements exist.

The materials, antiseep collars, pipe supports, and corrosion protection are the same for emergency spillways as they are for principal spillways.

Inlet structures shall have a trash guard and usual provisions for a headgate. Antivortex devices should be provided when full pressurized pipe flow is attained.

Headgates and valves shall be installed upstream or downstream from or in a valve well near the center line of the dam. Gate works will be adequately supported, and capable of operating under expected pressures. Valves should be protected against freezing and silting. Downstream valves should not be used where silting is expected to be a problem. An air vent is desirable downstream from the valve or gate, and is required where pipe velocities are expected to exceed 25 feet per second.

VISUAL RESOURCE DESIGN

Ponds in areas of high public visibility and those associated with recreation are to receive careful visual design. The embankment berms are to conform to the topography, and other aesthetic landscaping is to be considered.

DESIGN CRITERIA - EXCAVATED PONDS

Excavated ponds are impoundments created by digging depressions in the earth. Excavated ponds may be partially formed by berming the excavated materials on the downslope side of the impoundment.

DEPTH

Minimum depth will be eight (8) feet except where the water table is intercepted, where it will be two (2) feet lower than the lowest expected water table. The bottom area will be a minimum of 200 square feet.

SIDE SLOPES

Side slopes shall not be greater than 2 to 1, and 3 to 1 is preferable. Where livestock will directly water from the pond, a watering ramp will be provided. The ramp shall extend to the bottom of the pond at a uniform slope not to exceed 4 to 1.

RUNOFF

Provisions for a pipe and emergency spillway should be made where necessary (Table 10). Runoff flow patterns are to be considered when locating the pit and placing the spoil.

PERIMETER FORM

Where the impoundment is used for recreation, the perimeter should be curvilinear and aesthetically pleasing to the public view.

INLET PROTECTION

Where surface water enters the pond through a natural or manmade channel the side slopes of the pond shall be protected against erosion.

PLACEMENT OF EXCAVATED MATERIAL

The excavated material shall be placed or hauled away so its weight will not endanger the stability of the pond side slopes and where it will not be washed back into the pond by rainfall, using one of the following methods:

1. Uniformly spread to three (3) feet thick with the top graded away from the pond,
2. Uniformly placed at a natural angle of repose behind a berm equal to the depth of the pond or at least 12 feet high,
3. Shaped and blended to conform with the natural landscape, or
4. Used for low embankment and leveling.

DESIGN CRITERIA - FISH PONDS

Where the production of fish, crayfish, or other aquatic animals is desired, the State Biologist must be consulted concerning special design considerations. The following design criteria should be considered:

Less Than 25% of the Water is From a Running Water Source,

1. Minimum depth is 10 feet over at least 20% of the pond surface area.
2. Maximum surface area will not be less than one (1) acre.

Pond Has Continuous Through Flow,

1. The pond will have a minimum of six (6) feet of depth over at least 20 % of its maximum surface area,
2. Permanent surface area will not be less than

one-quarter of an acre,

3. Flood routing to determine the capacity of the principal spillway shall begin at the elevation of the principal spillway. The 70% empty criteria for farm ponds will not apply.

Other Specifications for Fish Ponds

Other specifications include those stated in this paragraph. Not more than 20 % of the pond will have a water depth of less than two (2) feet when the pond is full. The pond sideslopes should be abrupt from the shore to a point where the water is at least three (3) feet deep when the pond is full. This point should be within ten (10) feet of shore. Fencing should be provided, when necessary to prevent livestock intrusion. Pond drains will be provided for water level control necessary for weed control, fish population control, fish harvesting, mosquito control, and pond renovation. Special overflow discharge systems will allow for removal of water near the bottom of the pond. This facilitates temperature control, noxious gas control, and fertilization control.

Fish Losses and Introduction of Wild Fishes

Fish pond management is dependent upon proper stocking and prevention of loss of fish from ponds. Introduction of wild fish is also unwanted. These problems can be mitigated by spillway design, storage capacity control, and filtering. Spillways may be designed with shallow flow depths or with weirs. These design modes reduce the migration of fish into and out of the pond. Retarding storage in excess of the minimum retained by the principal spillway also helps retain the fish. Special filters of suran and other materials will prevent transfer of fish into and out of the pond.

TREES AND BRUSH

Removal of trees and brush below the high water line will be the concern of the State Biologist, who should be consulted regarding such actions.

DESIGN CRITERIA-WILDLIFE PONDS

The State Biologist must be consulted, where a pond's main purpose is to improve wildlife habitat. They will provide the special criteria and the site specific recommendations. Additionally, the following will be considered.

STORAGE

The difference between the lowest unvalved spillway and the lowest point on the dam center line shall be at least four (4) feet. This distance provides for one and one half (1.5) feet of freeboard, and two and one half (2.5) feet of flow depth in the unvalved spillway.

Surface Area

The surface of the dammed impoundment shall exceed one (1) acre, and the minimum surface area of a dug pond shall be one-half (0.5) acre. Fencing livestock out will be provided as necessary. When the surface area exceeds five (5) acres, consideration should be given to the construction of islands and loafing areas.

Depth

The pond shall be at least three (3) feet deep over at least 25% of the area.

Plans and Specifications

Plans and specifications shall conform to the SCS standard and allow for the achievement of the intended purpose of the project.

Construction drawings and plans should be based on and reflect thorough engineering, geological and hydrological investigations.

Applicable specifications shall be selected from the Wyoming Construction Specifications. These specifications will be used as a guide in preparation of construction drawings and details.

Construction shall be performed in a manner that reduces environmental impacts and discharges by erosion. Fencing and vegetative measures will be considered.

INDIAN LANDS

Indian Reservation Lands pose a significant and very complex situation to the water resource developer. The people concerned with these lands are at a loss when it comes to permitting small storage reservoirs on Indian Lands. Sovereignty issues, trust land issues, fee land issues and a whole host of other problems can arise when Indian Lands are used for water development. The basic sentiment is that someone would have to try it to find out how it works. It should be noted that Indian Lands are not public lands.

The Indians believe they have a sovereign right to regulate their own lands. They believe any permitting process should be their concern. Such matters as water development would have to go through the Tribal Water Engineer to be authorized. This Engineer, while concerned with the water and its uses, is not a controlling factor. Instead, the Tribal Water Engineer would be employed as a consulting entity, with either the Joint Tribal Business Council or the General Indian Council determining if water projects would be permitted.

The Tribal Water Engineer, as a consultant to the Joint Tribal Council and the General Council, would function to dictate the policies of the Shoshone and

Arapahoe Tribes. These Tribes regard themselves as sovereign governing agents of the Reservation Lands.

If this were true, the problem of water development on tribal lands would be a very simple issue. Go to the tribes with the proposal, and let them decide whether or not to grant the application. This is not the case; the only true sovereign is the United States of America, which means that the Indian Lands are subject to Federal Regulations dealing with Indian Lands. These Regulations fall under the Department of the Interior (DOI), and are enforced by the Bureau of Indian Affairs (BIA). This is where the issue of permitting water development on Indian Lands becomes complex. This is where Fee Lands and Trust Land issues come into play. The problem of permitting water projects on Indian Lands would likely result in a heated sovereignty battle, and not a water development battle.

As stated earlier the bulk of regulations apply to all dams. This is the end of the six feet dam height category. The regulations discussed to this point apply to all dams and storage reservoirs, and the regulations that follow add to the regulations found in the six feet category. The next height break point to be discussed is the 20 feet height.

<u>20 FEET DAM HEIGHT</u>

WYOMING STATE ENGINEER'S OFFICE

At 20 feet of dam height the Special Permitting procedure of the Wyoming State Engineer is no longer valid. A Professional Engineer or a Licensed Surveyor will be required for permit applications for dams in excess of 20 feet. The engineer will perform the necessary calculations and file the necessary forms with the Wyoming State Engineer's office.

It is also at this 20 feet level that the Wyoming State Engineer's office will make mandatory periodic inspections, every five (5) years, of the reservoir structures and appurtenance (WS 41-3-307). The associated storage capacity lower limit is 50 acre-feet.

This level of dam height requires that a spillway design flood generated by a 100 year storm be passed through the spillway with one and a half (1.5) feet of freeboard. As mentioned earlier, the USDA-SCS publication, POND is used in the State of Wyoming for small storage projects up to 40 feet in dam height as defined by the WSEO.

Erosive effects of such flowrates must be considered in the design of the spillway. Excessive velocities that result in excess erosion will be reduced by redesign of the spillway, or spillway lining of erosion resistant material such as grass, concrete, or asphalt (see POND).

Additional spillway capacity or spillway freeboard may be required by the Wyoming State Engineer. In the following table, Table 13, some of the criteria for the Regular Application will be illustrated.

Table 13. Wyoming Dam Design Guidelines

ITEM	REGULATION	COMMENTS
Drawings		
Cross Sectional	Profile of dam site at the center line, and maximum cross section of the proposed dam	Engineering detail of the dam is required for the review of the structure.
Outlet Works and Spillway	Outlet works and spillway in detail	Outlet works and spillways cross section with capacity calculations shown are to be provided.
Scale	Large enough to determine the necessary detail	Provide enough detail for the Wyoming State Engineer to determine adequacy of the proposed site.
1"=400'	For reservoir contour maps	
1"=1000'	For reservoir basins with two (2) mile widths or lengths	
1"=200'	For reservoir profiles	
1"=20'	For cross sectional plans	
1"=20'	For detailed plans including outlet works	Provide enough detail for evaluation.
Structural Dimensions		
Slopes	3 to 1 for the front or water side of the structure; 2 to 1 on the backside	Material dependent property.
Top width	(1/5) dam-height + 4 feet	

Table 13 (Continued)

ITEM	REGULATION	COMMENTS
Dam height	Measured from downstream toe to top of dam at center line	
Dimensions	State the length, width, and average depth	Used in the formula for capacity.
Beneficial Use	Provide a purpose for the water	
Off Channel	Provide water source information	Show the tie to the water source and the canal route.
Supply Ditches	Show the hydraulic properties and the cross section	
Lands to be irrigated	Clearly show the lands to be irrigated by the water	
Storage Breakdown	Show the breakdown of each beneficial use in acre-feet, this storage must correlate to the map's capacity table	Include inactive storage, but not possible future uses. Detailed breakdown of active use is to be provided. More than 20 acre-feet for stock water use is likely to be denied.
Surface Area	Indicate surface area when water is at the high water line	The high water line is the level of the uncontrolled emergency spillway crest.
Total Capacity	Indicate the total capacity	Total capacity is the capacity when the water is at the uncontrolled emergency spillway crest.
Location of Outlet	Show the location of the Outlet, Tie by course and direction to the nearest public land survey	Plans are required in sufficient detail to show the location and detail of the outlet structures.

Table 13 (Continued)

ITEM	REGULATION	COMMENTS
Land Description	Provide a description of Federal and State lands involved	This is required by a MOU with the WDEQ and the USCE.
Stream Name	Provide the name of the stream where the reservoir is located	
Supply Ditch Name	Provide the name of the supply ditch that will be the source of the storage water, and provide the appropriate permit number of the supply ditch and its name	If the reservoir is off channel, the supply source will not necessarily be the stream where the reservoir is located.
Construction Materials	State the construction materials, volumes, and methods	
Dam Face Protection	State the method of dam face protection	Methods include log boom, rip-rap, brush
Construction Time	State the projected construction completion time	Maximum time granted by the Wyoming State Engineer is 5 years.
Maps	Location and area maps are provided in the general reservoir permit procedure, The scale must be shown on the maps, Linen tracings will be provided	Location map locates the reservoir in the proper subdivision, and the area map shows the proper reservoir dimensions.
Directions	North Arrows	Arrows must be shown to indicate north.

Table 13 was derived from Part I of the Wyoming Surface Water Laws, and represents the basic requirements for a General Reservoir Permit (S.W.3).

The main differences between full permitting and Special permitting is the level of detail and expertise required. The General Reservoir Permit requires a Professional Engineer or Licensed Land Surveyor fill out the forms, design the structure and conveyance features, perform surveys, draw necessary maps, determine section ties and compute the volumes and capacities. The Special Permit does not require the use of such professionals, and the maps used may be USGS Quadrangle maps or aerial photographs. These differences reflect the hazard level of the proposed structure. The Wyoming State Engineer may require the full permitting in all cases if he determines the hazard is too high.

25 FEET DAM HEIGHT

USCE REGULATIONS

At 25 feet of dam height it becomes mandatory that the USCE inventory the dam and reservoir. This inventory process subjects the structure to an inspection of a detail commensurate with the structures hazard potential (33 CFR 222.8 h(1)). This inventory is required for all dams, federally owned or non-federally owned.

The various agencies are required to cooperate in this inventory to make efficient use of the work force, and thereby reduce costs. It is desirable to involve the States in their own programs. State programs are required to meet with the USCE's approval. Joint inspections and inspection forms and procedures intended to reduce the amount of paper work involved are encouraged. This paper work reduction conforms with federal guidelines to reduce red tape by eliminating redundant operations (40 CFR 1500.4).

Small Dams

Dams greater than or equal to 25 feet and less than 40 feet in height are considered by the USCE to be small dams. Small dams have a storage capacity of less than 1000 acre-feet, but greater than or equal to 50 acre-feet. Small dams have three (3) hazard classifications: low, significant, and high. These hazard classifications are derived from population density and economic loss should a dam structurally fail. These hazard classes are basically the same as for the NFS below, but the names of the hazard classes are different. Low hazard is predominantly rural with little economic damage, and no loss of life. Significant hazard is rural with some possible structural damage to downstream improvements. The USCE's significant hazard classification corresponds to the NFS's moderate hazard classification. High hazard classification is predominantly an urban setting with the possibility of loss of life, and extreme economic loss.

SPILLWAY SIZING

The spillway sizing is a function of hazard class and dam height. For small dams the spillway sizing for low hazard dams uses a Spillway Design Flood (SDF) of a 50 to 100 year frequency storm. Significant hazard small dams will use a 100 year storm's flood to a half (1/2) PMF (Probable Maximum Flood) to design their spillways. The high hazard small dams will use a half (1/2) PMF to a full PMF to design the spillway capacity.

NATIONAL FOREST SERVICE REGULATION

The NFS hazards are a function of dam height, the amount of water stored, and the downstream population density.

INVENTORY

The NFS will not inventory dams less than 25 feet high when they are of the moderate or low hazard variety, but is required to inventory and inspect other classes of dams not so excluded. All dams greater than or equal to 25 feet will be inventoried and inspected regardless of hazard class.

Hazard Assessment Classification

The NFS Hazard Assessment Classification deals with the potential for loss of life and property damage (NFS 7511.2). These three Hazard Classifications, low, moderate, and high will be discussed next.

Low Hazard

Low hazard dams result in minimal economic losses if failure occurs. These dams are located in rural areas of low population and structural densities. In low hazard situations the damage will be mainly environmental.

Moderate Hazard

These dams result in serious environmental damage and appreciable economic losses if failure occurs. These dams are located in areas with industrial development, commercial structures, transportation facilities, and public utilities that are likely to be damaged by dam failure.

High Hazard

These dams are located in predominantly urban areas where dam failure results in loss of life and considerable economic loss.

Administrative Classification

Class C Project

Class C projects are defined as those dams at least 25 feet high, but not exceeding 40 feet high. The storage range of Class C projects is less than 1000 acre-feet, but at least 50 acre-feet.

Spillway Design

For Class C dams the spillway sizing uses design flows that are based on hazard class. The low hazard Class C dam uses a 100 year storm's flood for sizing the spillway. The moderate hazard Class C dam uses a half (1/2) PMF for sizing the spillway, but incremental damage analysis may be used to reduce this SDF if applicable. The high hazard Class C dam uses a PMF for sizing the spillway, as is the case for all high hazard dams. These are minimum requirements for spillway sizing, that, when compared to USCE requirements show some differences. The differences are that the USCE provides a range with the NFS minimum requirement either contained in the range or less conservative than the USCE's Spillway Design Flood (SDF). Small USCE dams in the high hazard classification use a Spillway Design Flow (SDF) of half (1/2) the PMF to the full PMF, whereas the NFS uses a PMF for all high hazard class dams regardless of size. The NFS tends to require smaller SDF's for all but the high hazard class. This may reflect the nature of the lands under the jurisdiction of the NFS. The lands tend to be remote and rural.

35 FEET DAM HEIGHT

This is the upper limit of effective height for the applicability of the SCS publication, POND. This would be the same as the Administrative Height of 40 feet, if five (5) foot of freeboard were used. If this is the case, all dams constructed with the SCS POND specifications are what the USCE calls small dams. POND provides the general specifications that the WSEO uses when it checks dams for structural compliance (Benner, July 91).

40 FEET DAM HEIGHT

USCE REQUIREMENTS

INTERMEDIATE DAMS

Dams greater than or equal to 40 feet tall, but less than 100 feet tall are defined as intermediate dams. The storage capacity range is greater than or equal to 1000 acre-feet, but less than 50,000 acre-feet. These dams have the same hazard classes as the small dams (33 CFR 222.8, Appendix D, Chapter 2, Table 1). They are low, significant and high, and have been defined previously (33 CFR 222.8,

Appendix D, Chapter 2, Table 2).

SPILLWAY SIZING

For intermediate dams as defined by the USCE, the sizing of the spillways is dependent on the risk the particular structure poses if it fails. For intermediate dams of the low hazard variety the spillway sizing will be accomplished using a 100 year storm's flood to a half (1/2) PMF design flood. For intermediate dams of the significant hazard type the spillway will be designed to carry a half (1/2) PMF to a PMF design flow. Finally for the high hazard intermediate dams the spillway design flood (SDF) will be the PMF (33 CFR 222.8 Appendix D, Chapter 3, Table 3).

NFS REQUIREMENTS

CLASS B PROJECT

For Class B projects, the dam height upper bound is less than 100 feet, and the lower bound is greater than 40 feet. Along with this height criteria goes a storage range of greater than or equal to 1000 acre-feet and less than 50,000 acre-feet (NFS Draft 7511.1).

SPILLWAY SIZING

Spillway sizing of Class B dams is once again a function of Hazard Classification (NFS Draft 7511.2). The low hazard variety requires a minimum of a 100 year storm's flood be routed through the reservoir to size the spillway. The moderate hazard potential requires a minimum of a half (1/2) PMF be routed through the reservoir to size the spillway, though incremental damage analysis may allow a smaller SDF. The high hazard potential requires that a full PMF be routed through the reservoir to size the spillway (NFS Draft 7524.3).

100 FEET DAM HEIGHT

USCE REGULATIONS

LARGE DAMS

Dams greater than 100 feet tall are defined as large dams (33 CFR 222.8 Appendix D Chapter 2, Table 1). The storage capacity range is greater than or equal to 50,000 acre-feet. These dams have the same hazard classes as the small dams. They are low, significant and high, and have been defined previously (33 CFR 222.8 Appendix D, Chapter 2, Table 2).

SPILLWAY SIZING

For large dams, the sizing of the spillways is dependent on the risk the particular structure poses if failure occurs. For large dams of the low hazard variety the spillway sizing will be accomplished using a half (1/2)

PMF to a full PMF spillway design flood. For large dams of the significant hazard type the spillway will be designed to carry a PMF as a spillway design flood. Finally for the high hazard large dams the spillway design flood (SDF) will be the PMF (33 CFR 222.8 Appendix D, Chapter 3, Table 3).

NFS REGULATIONS

CLASS A PROJECT

NFS Class A dams are 100 feet or higher. Along with this height criteria goes a storage range of greater than 50,000 acre-feet (NFS 7511.1).

SPILLWAY SIZING

Spillway sizing of Class A dams is once again a function of Hazard Classification(NFS 7511.2). The low hazard variety requires a minimum of a 100 year flood be routed through the reservoir to size the spillway. The moderate hazard potential requires a minimum of a three quarter (3/4) PMF be routed through the reservoir to size the spillway. The high hazard potential requires that a PMF be routed through the reservoir to size the spillway (NFS 7524.3).

Crest Width

A minimum crest width of 28 feet is required of all dams over 100 feet. The formula for computing crest width, (35 + H)/5 ft, is used where applicable for smaller dams.

UNDER 150 FEET DAM HEIGHT

USCE REGULATIONS

Concrete Dams Under 150 Feet High

In addition to requirements previously mentioned the USCE has the following requirements for testing of materials properties and structural performance for concrete dams less than the 100 feet in height.

1. Hydrostatic uplift magnitudes and gradients under one or more monoliths.
2. Rates of inflow to drains from foundation, face, and joint basins.
3. Displacements of individual monoliths with respect to a fixed axis.

OVER 150 FEET DAM HEIGHT

USCE REGULATIONS

Concrete Dams Over 150 Feet in Height

In addition to the requirements for testing of materials and those specified for concrete dams under 150 feet the following are required for concrete dams over 150 feet (33 CFR 222.2 Appendix A).

1. Deflection and tilting monitors
2. Seismic response in seismic regions.

RESULTS OF THE STATUTORY SEARCH

ENVIRONMENTAL RESULTS

With respect to environmental concerns, it seems likely that the NEPA processes can be brought to bear in any project. With the NFS requiring an environmental evaluation, and the BLM performing a NEPA sort of reconnaissance and inventory of a proposed reservoir site, escaping the effects of the NEPA process is not likely. The code authorizing the various Federal Agencies mandates that agencies apply NEPA processes as early as possible, and explicitly indicates that NEPA processes be an integral part of the initial planning of any project. Even when the activities in question are seemingly excluded by a

Nationwide Permit, the appropriate Federal or State Agencies should be brought into the process to reduce the amount of responsibility on the applicant. Cooperation and compliance are the keys to avoiding the fines that may be imposed by the regulatory agencies.

The amount of streamflow should be less than 5 cfs on average to qualify as a headwater stream, and the amount of wetland disturbance should be kept to less than one acre, if the Nationwide Permitting is to be attempted. Off-channel reservoirs present an interesting alternative that is include under the Nationwide Permits as isolated watersheds. The off-channel reservoirs are discussed next.

Off-Channel Reservoirs

It appears that off-channel storage would cause less environmental concern than instream storage. Impacts that could be avoided are the destruction of mudflats or wetlands with the isolated basin or the off-channel impoundment. Site selection could eliminate these concerns by selecting sites without mudflats or wetlands. Off-channel storage may provide a method of mitigation for other projects proposed by the State.

Nowhere in the regulations are there any criteria for a SDF using an off-channel reservoir other than the requirement to account for sheet flow. This makes sense, especially if those facilities lie in isolated basins, and it is possible to control the water input from the diversion. This absence of stringent spillway design criteria would account for considerable savings on spillways.

<u>In-Stream Impoundments</u>

In-stream impoundments attract more scrutiny than off-channel type impoundments. Dredge and Fill (CWA 404), Water Quality Certification (CWA 401), wetland protection, floodplain protection, riffle and pool complex are a few of the standouts from the foregoing statutes that could effect the permitting of an in-stream impoundments. In the absence of suitable off-channel sites these in stream facilities are unavoidable, however.

DESIGN CRITERIA

With regard to dam height, the upper limit of feasibility seems to be 40 feet. Below this height the appurtenances and conveyance structures may be sized for a minimum of a 100 year storm for low and significant hazard levels. Even though the NFS Draft indicates a half (1/2) PMF be the SDF for moderate hazard, incremental damage analysis may be used to lower this value. It is believed that in Wyoming the SDF for most Moderate Hazard classifications could be lowered to the 100 year storm by an "Incremental Damage Analysis".

When an intermediate structure is proposed for any site with a moderate (significant) hazard site, a minimum design flood is one-half the PMF. It is at this level of one half (1/2) the PMF and larger that the definition of the design flood alone becomes a very debatable issue. Reevaluation of the existing criteria for determining these design flows by such methods as paleolithic flood flow evidence is ongoing at the time of this thesis. In general, however, the methodology in place, results in very large SDF's and thus costly appurtenance structures. It is believed that the design criteria for the PMF is highly inflated resulting in over-design of spillways (Jarrett, 1990).

GOVERNMENTAL AGENCY REQUIREMENTS

Governmental Agencies at the Federal level require the implementation of the NEPA process. This will involve the USCE and the USFWS for projects with significant adverse environmental impact.

Federal agencies usually accept State standards and criteria that are at least as stringent as the Federal Agency's. Much of the regulation pertaining to the USCE seeks to have the States form their own programs to administer such things as safety of dams, clean water certification, dam design criteria, safe drinking water and other programmatic issues.

The State of Wyoming is well rounded in its design criteria acceptance. The WSEO prefers to have its engineers well versed in the different departmental design standards, rather than requiring conformity to, and devising its own set of standards. The standards of the SCS, and the USBR are but two of the design criteria the WSEO engineers are proficient at checking (Dahlgren, August. 6, 1991).

Recommendations from the Statutory Investigation

It is the recommendation that the dam size of these small storage projects be less than 40 feet in height and have storage capacities of less than 1000 acre-feet. This will allow the structures to be constructed using a 100 year storm for the SDF for all but high hazard sites. It is unlikely that a site would be proposed or allowed for a high hazard site. Headwaters with average annual flows of less than five (5) cfs are usually in remote mountainous areas. Alternative sites to high hazard sites can nearly always be found .

CONCLUSIONS

It is concluded that the most cost effective and regulation free scenario for these small storage projects would be dams of less than 40 feet in height, storing less than 1000 acre-feet. These reservoirs should be located in areas with minimal acreages of wetland, riffle and pool complex, or mudflat. The sites should be consistent with Nationwide 26 requirements for headwater streams of less than five (5) cfs average annual flow, or isolated basins as discussed previously. The sites should not contain unique characteristics, or be inhabited by Endangered Raptors or Blackfooted Ferrets. These are the only T&E species presently surveyed for when the USFWS assesses a possible construction site, because the endangered Wyoming Toad would benefit from additional wetlands provided in its range. Sites should also be chosen to best situate several small storage projects in close proximity. Dendritic type basins provide this type of situation. This site situation allows for a more efficient and effective control of the projects, minimizing conveyance losses. It is also concluded that the NEPA process should be initiated early in the project's planning and design stages.

CHAPTER IV
Rationale Behind the Site Selection

With the conclusion of the statutory investigation, the remainder of the paper will be devoted, first in Chapter IV, to developing the logic behind site selection, then in the remaining four chapters to modeling, results of modeling, analysis of the results of modeling, and finally in Chapter VIII to conclusions. This chapter discusses important information resulting from the statutory search that will dictate what a feasible small storage project is.

WATER AVAILABILITY

The compacts, assumed impact issues, knowledge of the water allotments remaining and precipitation amounts were all considered part of the site selection. Water available after the constraints were applied was an objective function for part of the logic behind site selection.

AUTOMATICALLY RULED OUT

Indian Lands were ruled out as too controversial and unnecessarily complicated. Sites that might involve wilderness areas or unique ecosystems were also ruled out for the same reasons.

The Special Permits for stockwater/domestic water, fishing preserve and flood detention are to restrictive in the use of the waters detained and are not a serious option. The capacity of these reservoirs is too small. Because Special Permit structures cannot be used, full State permitting will be required.

COMPACTS AND COURT DECREES

The compacts indicated that some areas were more suitable than others for the small storage project sites. Consideration of the compacts and decrees ruled out the Niobrara, the Snake, North Platte, and the Laramie Rivers. These areas have supply problems that result from the compacts or from precipitation deficiencies. The Snake River, the Laramie River, and the North Platte are the most likely to be politically problematic. The Niobrara River and the Belle Fourché River may suffer from supply problems.

The basins of the Bear, Bighorn and Green River all have unallocated water left that could be stored. The Inyan Kara Creek area of the Belle Fourche' River allows for unlimited 1000 acre-feet impoundments, and has a demonstrated supply (SCS, 1992).

Mitigation for wetlands loss would be an issue in all of these basins, but an additional mitigation issue exists in the Green River drainage. Mitigation will be required for any project on the Green River because of the endangered fish on the lower reaches of the Green River (Western Area Power Association (WAPA), 1989).

NEED

Projects should be proposed for areas with a demonstrated need for the water. This seems obvious, but is sometimes overlooked. The USCE, the BLM and the NFS all require that a project provide a beneficial use in accordance with the agency's land usage plan. Present pressing needs are looked on favorably, while long range projected uses are looked upon as speculative and not feasible (Blinkhorn, 1991).

Most areas of the State have demonstrated a need for water at one time or another. The area of the Nowood, Gooseberry Creek, Pinedale, Big Piney, Sundance and arid regions south of Cody have demonstrated a clear and present need for irrigation waters.

SITE REQUIREMENTS

Sites were selected by an systematic interdisciplinary review. Sites selected were such that the reservoirs will hold water and not have excessive infiltration. The basins should not contribute excessively to silting of the reservoir, making the reservoir what is known as a "sediment catcher" (Jackson, July, 1991). The relief should be such that dam heights of less than 40 feet will result in reservoirs approaching, but not exceeding 1000 acre-feet storage capacity. The sites were selected so as to minimize the use of environmentally sensitive or unique areas. Sites were selected that do no harm to Threatened and Endangered (T&E) species. Further, sites were close enough to the proposed use that conveyance losses are kept to a minimum. Dendritic drainage basins were sought to make management more effective. Sites were located where gaging station records or precipitation records exist, if possible. This was necessary for the third part of the feasibility study to have creditability. Finally, the sites were located on headwater streams or in isolated watersheds as the original project specified.

With all these things in mind, the following sites were selected:

1. Inyan Kara Creek (Tributary to the Belle Fourche' River)
2. Gooseberry Creek (Tributary of the Bighorn River)
3. La Barge Creek (Tributary of the Green River).

The rationale for these sites are summarized below.

Inyan Kara Creek

Inyan Kara study area is located in Northeastern Wyoming thirteen (13) miles South of the town of Sundance, Wyoming. The drainage basin area of this study area is 94.59 square miles. The area includes regions in the Black Hills; thus the topography is rolling hills. The simulation for the modeling will include three dams located on Inyan Kara Creek proper. One of the storage projects is located above the confluence with Soldier Creek; the other two are located below the confluence of Soldier Creek.

The SCS has looked at this area for a storage - flood control facility for some time. The major hold up is money. Possibly, with State and Federal involvement, the project may get beyond the planning stages. The area is subject to flash flooding. With the bentonite in the lower basin, the curve numbers would be high, making runoff high also. The upper regions of the drainage have less bentonite, and thus moderate runoff potentials. If this upper basin water can be detained and put to use in irrigation, it will also alleviate some of the flood potential downstream. The ranchers of the area have shown an interest in storage and flood control, but cannot agree on how to pay for such projects.

Gooseberry Creek

Gooseberry is another study site for proposed reservoirs. This area is located in Northwest Wyoming, 30 miles Southwest of the town of Meeteetse, Wyoming in the Absaroka Mountains. The Gooseberry Creek study area is 71.57 square miles of predominantly mountainous terrain. Three storage projects were modeled for this study area. The storage facilities were all on the main branch of the stream in series.

This area had a USBR project proposed. Water exists for this larger project (Jackson, 1991). Initial topographic investigation indicates the possibility of off channel sites in this drainage basin. The ranchers of the area would like more water in the late summer months to improve harvests.

La Barge Creek

The La Barge Creek study area is located high in the Wyoming Range of Western Wyoming, 25 miles West of the Town of La Barge, Wyoming. The La Barge Creek study area has an area of 55.95 square miles. The model of this area contains two reservoirs located on the main branch of La Barge Creek above the confluence with South La Barge Creek, and one reservoir on the South Fork of La Barge Creek.

The Green River Basin has unallocated water. The ranchers would like more late season water to insure good crops even in dry years. The area above the Forest Service guard station may qualify as a headwater area. The creek has a flowrate of less than five (5) cfs for at least six (6) months of the year for a majority of years. Willow meadows are a prominent feature of the La Barge drainage.

With the sites selected using the statutory search as the evaluating criteria for regulatory feasibility, the sites were next evaluated for their H&H (Hydraulic and Hydrologic) feasibility.

CHAPTER V
Data Collection, Methods of Analyses, Small Watershed Modeling and Simulation

DATA

Data for the project areas was obtained from the Wyoming Water Resources Center. These data include precipitation and stream flow records for various stations in and around the study areas. For Inyan Kara the records from Redbird will be used for required precipitation data. Stream flow records used in the Inyan Kara study area are from a temporary gaging site at the highway bridge west of Upton, WY. For La Barge, since a good portion of the drainage basin lies in a mountain high precipitation zone, it was believed a composite method should be developed to reflect the elevation precipitation differences caused by orographic effects. This composite should include snowfall data from area snow courses, and rainfall data from Viola, the nearest rainfall recording station. Because the correlating temperature and daily snow depth data did not exist this rationale could not be used. For Gooseberry Creek, a procedure similar to that used for La Barge Creek should be used, but could not because of the lack of data.

PRECIPITATION EVENT DEVELOPMENT

Because of the lack of data, a NOAA publication was used to determine the amount of gross precipitation of a 100 year event. For the La Barge area a 24 hour-100 year storm was used. This is because the extreme runoff events typically occur due to snowmelt, and it is assumed snowmelt is better simulated by a general storm of 24 hour duration. In the east, and in particular the Gooseberry Creek and Inyan Kara study areas, the precipitation event chosen for modeling purposes was a six (6) hour-100 year storm. This particular storm was chosen because typically the major flood events occur in July and August, indicating thunderstorm events generate such floods. It is generally accepted that a thunderstorm of six (6) hours yields the larger runoff events so the six (6) hour storm was adopted. The NOAA publication adjusts for elevation in the equations used and on the maps for the different duration Mean Recurrence Interval storms (MRI). The gross precipitation from the NOAA publication was used with spatial reductions described as follows.

The spatial reductions to the gross amounts of precipitation were obtained from Hydrometeorological Reports No. 55A and 49 (HMR 55A & HMR 49). HMR 55A was used for the Inyan Kara Creek and the Gooseberry Creek study areas. HMR 49 was used for spatial reduction for the La Barge study area.

The distribution of these storm events was derived from two different sources. The first is HMR 49, and the second is a Crow Creek Phase II Study by ESA Consultants of Fort Collins, Colorado. The ESA methodology was chosen as representative of Phase II studies on the eastern slope of the Rockies. These distributions will be used to distribute precipitation once adjustments are made for area and elevation.

SIMULATION METHOD

The abstractions to the precipitation distribution were performed by the Hydrologic Engineering Center Program 1 (HEC 1). This program simulates runoff and routing of a series of sub-basins, given precipitation, hydrograph, hydraulic, hydrologic, abstraction, and geomorphologic data. HEC 1 was chosen because of its capabilities of simulating snowmelt and dam breaching. This program was used to simulate the design storms over the study drainage basins, and route the floods produced by the storms through reservoirs and stream reaches. Before HEC 1 is used, many parameters must be estimated or determined. Equations used by the HEC1 program may be found in any HEC1 manual.

PARAMETER ESTIMATION

To develop lag time (t_l), an SCS equation developed by Victor Mochus in 1950 was used. Resultant lag times are found in Appendix D. The SCS program TR55 (Technical Release 55) was used to compute the runoff curve numbers (RCN), the reach travel time (Tt), and the time of concentration (Tc) for La Barge and Inyan Kara study areas. Parameters for the Gooseberry Creek area were derived from a Morrison Knutson Phase II study of the area. Parameters developed by TR55 were used to corroborate empirically derived values where possible. Curve numbers that best reflect the 100 year flood as determined by HECWRC (Hydraulic Engineering Center Water Research Center) for log Pearson III flood statistics were used (Appendix B). This lead to AMC II curve numbers for La Barge and Gooseberry Creeks. The values are 70 and 65 (78 downstream) respectively. The Gooseberry Creek area has a different RCN for the upper basin than the lower basin. The use of AMC II curve numbers leads to flowrates that more closely approximate station values for the 100 year event when the sub-basin amount was multiplied by an area ratio to obtain a runoff at a gaged point. Input files for the HEC 1 runs are indicated in Appendix A.

A nearby Phase II study was used for La Barge as a check of curve numbers estimated by the author. The Smiths Fork Creek, over the divide to the west from La Barge Creek, has a recent Phase II study. This study yielded an AMC II curve number of 75 for La Barge Creek. Printer files for the TR55 runs for these basins are found in Appendix C.

ROUTING PARAMETERS

Other parameters needed for simulation, such as the Storage Discharge relationships for the reservoirs and stream reaches were estimated from stream cross sections derived from limited knowledge and topographic maps. Because Kinematic Wave Routing was used in the channels, and the sections where the reservoirs were placed was short, no reduction of routing distance due to the reservoir was performed. This was justified because the inflow and out-flow hydrographs of these reaches were nearly superimposed on one another. Reservoir elevation versus height relationships were estimated from topographic maps and the conical method for volume calculation. Areas used for the conic method were estimated by a relationship devised to use the longitudinal slope and cross sectional slope versus stage to give a base length and a base height. This height and length will be a product with a constant.

This product is set equal to the area at the top of the dam; in this way a constant for the reservoir was determined. Once the precipitation and abstraction are determined, they are used with lag time to develop sub-basin hydrographs. HEC 1 was then used to combine hydrographs, river route and reservoir route to simulate the precipitation event in the study basin.

SPILLWAY SIZING

When the study area was modeled, three dams were placed in each of the three study area models at locations found to be suitable by reconnaissance. The model was then run with the low level outlet plugged to develop the proper spillway size. A freeboard of one and one half (1.5) feet is a minimum requirement; this allows for three and one half (3.5) feet of flow depth over the spillway. A spillway coefficient of 2.54 was developed using USBR Small Dams, and Handbook of Hydraulics, by Brater and King, and an exponent of 1.5 was used. These parameters are typical of broad crested weirs.

APPURTENANCE PARAMETERS

A simple outlet pipe was chosen as the regulated outlet for each reservoir. The intake of the outlet pipe to be placed as close as practicable to the lowest elevation of the reservoir. An orifice coefficient of 0.6 was chosen, and is conservative by USCE standards. The exponent used was 0.5. These values were recommended by the HEC 1 manual, and were determined to be accurate in so far as Brater and King published values near these estimated values. A value of 1.4 was calculated using the energy equation and USBR methodology. Thus the .6 value is very conservative. When the cross sectional area of 7.07 feet squared was calculated using the energy equation it was assumed that a minimum of 25 cfs should be the capacity at five (5) feet of head. This would allow for an instream flow of 25 cfs during the high flow season and 17 cfs during the low flow season for La Barge Creek. La Barge Creek would have set values for outlet appurtenance flowrates because it is the only studied area stream with an instream flow requirement.

OVERTOPPING PARAMETERS

The weir expression used for dam overtopping, 1.5 was used for both the coefficient and the exponent. These are the values used in the HEC 1 manual, and were used as default values. These parameters are basic broad crested weir values.

DAM BREACH PARAMETERS

The parameters used for the dam breach mode in HEC 1 were arrived at through consultation with Russ Dahlgren at the State Engineers Office, through referencing the HEC manual, through referencing Simplified Dam Break (Fread, 1991), through referencing Technical Release 60 (TR60)(210-VI-TR60, Oct. 1985) , and through referencing USCE envelope curves. These references lead to the use of a full height breach of trapezoidal cross section with 2 to 1 side slopes and a bottom width equal to the height of the dam (40 feet). The pre-breach water level was set to the brink of the emergency spillway. The time of failure was set to 15 minutes (1/4 hour). The type of breach modeled was a clear weather breach with reservoir full. The simplified models indicate the parameter selection for the HEC 1 breach run were in the ball park with the envelope curves and the empirical relationships developed by the various agencies.

With all the various parameters compiled, HEC 1 compilations for normal flow patterns, for spillway design, for normal function with the dams, and for dam breach were run. These runs used data for the conditions that best generated the 100 year flood, as determined by HECWRC, with the 100 year NOAA precipitation event as distributed by methods previously described. Input Files for HECWRC may be found in Appendix B. It should be noted that the HEC 1 runs of La Barge Creek used a fix point numeric scheme because the normal Newton-Raphson scheme did not converge. This failure to converge is due to the small descretization of the study area. The results of the La Barge Creek HEC 1 run, and the HEC 1 runs of Inyan Kara Creek and Gooseberry Creek are the subject of the next chapter.

CHAPTER VI
Results of Modeling

FLOOD FLOWRATES

Table 14 indicates flowrates for the study streams before dams (Normal), after dams with spillway, but without outflow structure in use, after dams with spillway and outflow structure in use, and finally for dam breach conditions. For the normal basin before dams, flowrates will be given at the location of the future proposed dam. Where the dams exist, the flood flows will be routed through the reservoirs. It should be noted, that while the reservoirs on Gooseberry Creek and Inyan Kara Creek are in series, Dam 3 on La Barge Creek is on the South Fork of La Barge Creek. The flood flow for this reservoir, therefore seems out of place. The Out in the area column indicates the outflow from the study area, for instance La Barge Out is the outflow from the La Barge Study Area.

Table 14. Flood Flows

Study Area	Normal Basin cfs	Spillway Design cfs	Normal Dam Operation cfs	Breach Conditions cfs
La Barge Dam 1	574	566	558	22849
La Barge Dam 2	868	801	759	50584
La Barge Dam 3	217	208	197	16293
La Barge Out	1628	1634	1522	31308
Gooseberry 1	224	181	197	30172
Gooseberry 2	444	297	343	40375
Gooseberry 3	495	235	343	38914
Gooseberry Out	444*	224	343	37026
Inyan Kara 1	420	362	285	40124
Inyan Kara 2	1640	1699	1836	45763
Inyan Kara 3	1915	1774	1926	62005
Inyan Kara Out	2035	1774	1926	40659

* routed without additional flow.

It is obvious from the flows in Table 14 that the reservoir tends to attenuate the flows as well as diminish the peak of the flow. It is also true that this dispersion and peak reduction is less with the Kinematic Wave routing than it might be with some other routing method, or what may actually occur. The normal operation of a reservoir shows less of this dispersion and peak reduction because the outlet works is flowing. In a more normal situation the outlet would not be opened fully as in the model. What is also obvious, is that while these reservoirs do afford some flood detention, they also subject areas below them to PMF type events should they fail by breaching.

RESERVOIR AND DAM SIZE

The use of a 40 foot high dam gives a wide variation of storage. This storage is dependent on the geomorphic characteristics of the basin at the dam site. In general, minimization of materials is sought, and selection of a site in a canyon is desirable. At such locations the stream gradients are steep, and 40 feet of dam results in little more than filling the canyon section. These reservoirs resulted in very little storage. Conversely, when an open section was chosen for a dam site, the materials required for dam construction are large, but the resulting reservoir has more storage. This is an interesting dilemma, but it was somewhat expected. It may be that evaporation and infiltration may play an important role in these small storage projects.

The dam cross section will be considered to be the standard 3 to 1 upstream slope and 2 to 1 downstream slope, with rip rap provided for wave erosion. A zoned dam meeting proper filter requirements and supplied with drains is desirable. Downstream slope protection should also be provided. Various methods of accomplishing these objectives may be found elsewhere in this thesis.

Table 15 illustrates dam lengths and storage amounts for the various proposed small storage reservoirs. The storage is given in acre-feet, and the dam lengths are given in feet. The storage given is for the full condition, and all dams are the standard 40 feet high.

Table 15. Dam length and Reservoir Storage

Study Area	Dam Length	Reservoir Storage
La Barge 1	500	257
La Barge 2	700	377
La Barge 3	400	200
Gooseberry 1	600	343
Gooseberry 2	1000	572
Gooseberry 3	1000	520
Inyan Kara 1	600	572
Inyan Kara 2	400	629
Inyan Kara 3	200	512

OUTLET WORKS SIZING

As stated earlier, the outlet works for all study areas was designed to flow 25 cfs at five (5) feet of head. Additionally a few minor losses were included. The resulting outlet pipe has a 7.07 square feet cross section. The exponent is 0.5 and the coefficient is 0.6. The run lengths for the pipe and the appurtenances are assumed to be standard trash racks, pipe bends, pipe valves, air relief fittings and outlet stilling structure.

SPILLWAY SIZING

Table 16 illustrates the spillway width, freeboard, and flow depth for each of the dams in each study area. Values given are for spillway operation with outlets operating, but spillways were designed to convey the flood without operational outlet works.

Table 16. Spillway Sizing

Study Area	Spillway Width in feet	Spillway Freeboard in feet	Spillway Water Depth in feet
La Barge 1	40	2.7	2.3
La Barge 2	50	2.3	2.7
La Barge 3	16	1.9	3.1*
Gooseberry 1	15	2.2	2.8
Gooseberry 2	18	2.9	2.1
Gooseberry 3	20	3.0	2.0
Inyan Kara 1	22	3.7	1.3
Inyan Kara 2	105	1.7	3.3
Inyan Kara 3	110	1.6	3.4

* outlet will handle flood without spillway

The preceding was a tabulation of the data generated with HEC 1. The data provides useful information for studies such as small storage project feasibility. The interpretation of these data and results will be presented in CHAPTER VII (Analysis and Evaluation of Results of Modeling).

CHAPTER VII
Analysis and Evaluation of Results of Modeling

GENERAL

The results of modeling indicate much that was expected, and some that was not. Each aspect of the output of the HEC 1 runs will be discussed along with their perceived ramifications. These results will then be used to determine an outcome, if possible, for the feasibility of small storage projects as alternatives to large storage projects. Input files are found in Appendix A, Input Files.

DESIGN STORM AND SPILLWAY SIZING

When constructing a dam, often the highest cost is the spillway. If a smaller storm can be used to generate a SDF the spillway cost will be lowered. This seems logical, and this study has indicated smaller spillways may be used for spillways designed with 100 year storms.

Spillways on the order of 15 feet in the Gooseberry Creek study area to 110 feet in the Inyan Kara study area are much smaller than if they were designed for a half (1/2) PMP or a full PMP storm. The storms looked at for a 100 year MRI were two (2) to three (3) inches of total precipitation. These storms yielded runoffs of around 500 cfs in the Gooseberry Creek area to just over 2000 cfs in the Inyan Kara area. The La Barge area was around 1675 cfs. These were outflows from the study areas before dams. One would expect flows in excess of 30,000 cfs for PMF's in the La Barge and Gooseberry areas, and even higher in the Inyan Kara area, where the PMP is very large.

Gross unadjusted PMP amounts for the Gooseberry Creek area from HMR 55A is 13.5 inches, from HMR 55A for the Inyan Kara area is 23.5 inches, and from HMR 49 for the La Barge area is 13 inches to 14 inches for July. These PMP figures would lead to larger spillways. From the stand point of spillway size alone, smaller projects may be cost effective because spillway design flows are small.

RESERVOIR STORAGE

In basins where stream gradients are steep, a 40 foot dam does not yield much storage. Whereas, a 1000 acre-feet impoundment may be permitted, a 40 foot dam may yield only 200 acre-foot of storage. This is what was found in the La Barge Creek area, where the steepest gradients (~0.3) exist. The largest reservoir in this area was 377 acre-feet and the smallest was 200 acre-feet. Conversely, in the Inyan Kara region the gradients were less steep (~0.11) the reservoirs were 629 acre-feet for the largest to 512 acre-feet for the smallest. Gooseberry Creek area gradients were intermediate (~0.25), and so were the reservoir sizes. The largest Gooseberry Creek reservoir was 572 acre-feet, and the smallest was at 343 acre-feet. This indicates an inverse relationship between basin slope and storage capacity, if dam height is held constant. This is to be expected, as is a steeper gradient as one moves further up on headwaters of streams. The HEC 1 input data for stage versus storage is found in Appendix E.

DAM LENGTH

A relationship exists between dam length and reservoir capacity; the longer the dam, the more storage capacity. This relates to an observance of stream nature. It seems as though in canyons, where dam length can be minimized, saving material costs, the stream slope is steep. Undoubtedly the stream slope is due to the geomorphology. The steeper slope in canyons indicates the need for a dam higher than 40 feet to back the water out of the canyon, where storage is in a basin, not a trough. When a site existed, where materials could be minimized, the 40 foot of dam height required to stay in the low hazard class was inadequate to generate storage. Just what kind of costs are substantiated for dam building will be a driving factor in deciding the cost effectiveness of many of the small reservoirs. Some of the choice locations for reservoirs were abandoned due to the fact that the reservoir would effect large tracts of wetlands.

It concerns the author, that if a long dam is utilized to develop storage, a large evaporation basin may be formed. If the small reservoirs are filled once a year as required by law, and if this filling must be performed when no direct flow rights are effected, as in the winter and early spring, no storage may exist by late summer when the storage right is needed.

ROUTING

Since the routing for the modeling was performed by Kinematic Wave, it is reasonable to expect the modeled flows to be conservative. No attenuation or peak reduction occurs in a planned manner with Kinematic Wave Routing, but rather, is a result of numeric diffusion. Therefore, the models, as constructed are a worst possible case. The models were reasonable simulations in the absence of accurate surveys.

DAM BREACH FLOWS

The flowrates generated by the model for dam breaches in sequence, with clear weather conditions were very large. At first this was believed to be in error, but the flowrates were compared to flowrates of the USCE and some values generated by NWS Simplified Dam Break Routines. This comparison indicated the values generated by the model were acceptable.

The values generated for dam breach are found in Table 14, and resemble flows one would expect of a PMP type event on the watershed. The additional risk imposed by such structures will undoubtedly be questioned in a cost benefit study of such structures. Downstream development will dictate the outcome of such a study.

FLOOD CONTROL

The output of the HEC 1 runs indicate the dams function to attenuate and decrease the peak of the flood wave. This is normally expected of a reservoir, even when its function is not primarily flood control. Increased flood control effectiveness is expected, if the reservoirs are not full. This may be looked at as a benefit for such systems. They are literally a cascade of linear reservoirs.

CHAPTER VIII
Summary, Conclusions and Recommendations

SUMMARY

This study evaluated statutes to determine effective sizes for small storage reservoirs. From law it was decided that a small storage project structure should not exceed 40 feet in total height, and should be located in rural settings. This total height allows for the storage of 35 feet of water at the high water line a requirement of low hazard classification. From law it was determined that these dams should not impound more than 1000 acre-feet of water so as to meet low hazard classification requirements. From law it was determined that no more than 1 acre of wetlands should be effected by the waters of the reservoirs created by these dams. From law it was also determined that these reservoirs and dams should be placed in headwater or isolated basins to qualify for Nationwide Permitting, which allows for construction with minimal environmental red tape. Following these guidelines, a structure could be constructed without the expense of

Environmental Assessment (EA) and/or Environmental Impact Statements (EIS). The projects could also have spillways sized using a 100 year storm, thereby reducing spillway costs.

Three areas were chosen in which to model these structures and reservoirs. They are La Barge Creek, Gooseberry Creek, and Inyan Kara Creek. Inyan Kara provided the reservoirs with the most storage at the expense of long dams and large spillways. Gooseberry Creek provided intermediate size reservoirs with the smallest spillways, but at the expense of long dams. La Barge Creek provided the least storage; the dams were shorter, and the spillways intermediate.

All of the areas were put at risk of very high flood flows should a dam breach occur with clear weather full reservoir conditions. Dam breach flows were the least for Gooseberry Creek, the most for Inyan Kara Creek, and La Barge was intermediate.

While none of the study areas developed the 1000 acre-feet of storage sought, many were over 500 acre-feet. These might provide enough storage for a small irrigation project or for a municipality. The risks are breach flows, evaporation and seepage losses, and the high cost of dam construction.

CONCLUSIONS

The study indicates small storage projects in headwater areas, where wetland and dredge and fill exemptions exist, may be a feasible alternative method of water storage, but not as a replacement for large storage structures. This conclusion would apply in other states of the inter-mountain region where headwater gradients are steep.

When one considers the number of small storage projects required to equal one Smiths Fork Project, for instance, it is obvious that small storage projects are not feasible. Smiths Fork is used as an example because of its proximity to the La Barge study area. In this area, gradients are steep, and reservoirs are small, many 250 acre-feet reservoirs would be required to equal a 125,000 acre-feet Smiths Fork Project. Is the cost of 500 small spillways off set by the cost of one large spillway? Probably not, but the small storage project still has its place for use where small amounts of water need to be stored for purposes such as municipal use, or small irrigation projects. The Army Corps is not likely to allow more than three (3) per basin without requiring full EIS, EA type scrutiny. This also limits the use of the small reservoirs to something other than replacements for large reservoirs. Also, in regards to La Barge Creek, the reservoirs were located downstream of the point of the discontinued La Barge Creek Ranger Station gage. It was at or above this gage that a five (5) cfs flow would not be exceeded 50 % of the time. Above this gage is the choicest spot for a reservoir in the entire basin, but could not be used because of historic and wetland issues. The wetland issue is La Barge meadows; the historic issue is the Lander Cutoff of the Oregon Trail. Until the environmental and historical protective mechanisms are changed, do not look for this ideal site to be utilized.

It becomes apparent that the small storage reservoir is useful when small amounts of storage are required, and the owner wishes to build them with as little red tape as possible. The one thing these small reservoirs do is minimize the amount of wetland effected.

Storage in headwater streams is limited. This study indicates that areas where headwater slopes are steep may be unsuitable, if 1000 acre-feet of storage is desired. To attain 1000 acre-feet of storage, a higher dam than the 40 foot dam used for the low hazard classification would be required.

It is probable that a community looking for a fast water storage source may find small storage facilities as defined by this thesis the most economic and permit free way of obtaining storage. It is also possible for irrigators to use this thesis to define parameters for building storage reservoirs with the least amount of regulatory scrutiny. Whether these reservoirs are cost effective for these two purposes will vary from application to application. What is known is that a series of smaller reservoirs should not be thought of as a replacement for large storage projects.

RECOMMENDATIONS

Since small storage projects as defined in the thesis in mountainous headwater streams do not provide the 1000 acre-feet, a more exhaustive search for off-channel isolated basin storage may be in order. Isolated off-channel basins were looked for in this study, but none with high capacity were found. This type of storage would be largely free of wetland issues, spillway sizing requirements would be minimized for precipitation in the contributing basin, and no storage limitations, outside water right issues, would exist.

As a replacement for large storage projects in Wyoming's Yellowstone River and Green River basins, six (6) feet high dams on the terminal moraines may be considered to obtain large amounts of detention storage without a lot a legal encumbrance. These six (6) feet dams would not be inventoried, and using the City of Pinedale's two (2) foot extension on Fremont Lake in Wyoming as an example, would provide large amounts of storage. Even if this storage was not irrigated with, it would provide late season flow attenuation due to increase aquifer storage in the glacial moraines of the areas.

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APPENDIX A
HEC 1 Input Files

La Barge Creek Input Data

```
ID          LA BARGE SIMULATION ON HEC-1
ID          AMCII CONDITIONS
ID          STREAM DRAINAGE NETWORK MODEL
*DIAGRAM
IT    15 15MAY92    0000      300
IO     3       0       0
KK  SUB1          HEADWATERS OF LA BARGE CREEK
KM          SCS RUNOFF COMPUTATION
BA  3.11
IN    60
PI   .05     .05     .05     .05     .05     .05     .32     .32     .32     .32
PI   .32     .32   .1133   .1133   .1133   .1133   .1133   .1133    .057    .057
PI  .057    .057    .057    .057
LS     0      70
UD 11.21
KK  RCH1
KM          ROUTE SUB1 TO JCT2 WITH KINEMATIC ADDITION
BA  1.74       0
UK   350     .34     .34     100
RK  2000     .24     .05      .1    TRAP       0
RK  7075    .011     .03            TRAP       8       2     YES
KK  SUB3          SCS UNIT GRAPH FROM SUB3
KM          RUNOFF FROM SUBAREA 3
BA  1.06
LS     0      70
UD   5.6
KK    J2          COMBINE SUB3 AT JCT2
KM          COMBINE ROUTED FLOW AND SUB3 AT JCT2
HC     2
KK  RCH2
KM          ROUTE COMBINED SUB1 SUB2 SUB3 TO JCT3 WITH KW ADDITION
BA   .32
UK   350     .27     .34     100
RK  1000      .1     .05     .05    TRAP       0       1
RK  4752    .014     .05            TRAP       6       2     YES
KK  SUB5          SUB5 UNIT SCS GRAPH
KM          HYDROGRAPH SCS FOR SUB5
BA  1.38
LS     0      70
UD   5.9
KK    J3
KM          ADD SUB5 TO ROUTED FLOW AT JCT3
HC     2
KK  RCH3          ROUTE AND KW COMBINE TO JCT4
KM          ADD KW TO FLOW AS ROUTE FROM 3 TO 4
BA   .54
UK   350     .28     .34     100
RK   200      .1     .05     .05    TRAP       0       1
RK  3801    .021     .05            TRAP       6       2     YES
KK  SUB7
```

```
KM          GENERATE SCS UH FOR SUB7
BA   1.8
LS     0      70
UD   7.5
KK  SUB8
KM          GENERATE HYDROGRAPH FOR SUB8
BA  1.38
LS     0      70
UD   6.6
KK    J4
KM          ADD SUB7 AND SUB8 TO ROUTED FLOW AT JCT4
HC     3
KK  RCH4          ROUTE TO JCT5 WITH KW ADDITION
KM          KINEMATIC ROUTE AND FLOW PLANE ADDITION
BA   .49
UK   200     .33     .34     100
RK   500      .2     .05     .05     TRAP      0      1
RK 13132   .0105     .05             TRAP      8      2     YES
KK SUB10          SUBAREA 10
KM          DEVELOP SCS UNIT HYDROGRAPH FOR SUB10
BA  3.37
LS     0      70
UD   9.1
KK    J5          ADD SUB10 AT JCT5
KM          ADD SUB10 TO ROUTED FLOW AT JCT5
HC     2
KK  RCH5          ROUTE AND ADD KW TO 6
KM          ROUTE 5 TO 6 AND ADD KW FLOW
BA   1.9
UK   250     .33     .34     100
RK  2000     .15     .05     .05     TRAP      0      1
RK 13031    .012     .05             TRAP      8      2     YES
KK SUB12          SUBAREA 12
KM          DEVELOP SCS UNIT HYDROGRAPH FOR SUB12
BA  2.86
LS     0      70
UD  10.5
KK    J6          ADD SUB12
KM          ADD SUB12 TO ROUTED FLOW AT JCT6
HC     2
KK  RCH7          ROUTE AND ADD
KM          ROUTE DAM OUTFLOW AND ADD KW FROM 13
BA  1.01
UK   300     .18     .34     100
RK  2000     .10     .05     .05     TRAP      0      1
RK  3326    .001     .05             TRAP      8      2     YES
KK SUB14          SUBAREA 14
KM          DEVELOP SCS UNIT HYDROGRAPH FOR AREA 14
BA  1.52
LS     0      70
```

```
UD   4.4
KK SUB15          AREA 15
KM          DEVELOP SCS UNIT HYDROGRAPH FOR SUB15
BA   .46
LS     0      70
UD   4.9
KK SUB17          AREA 17
KM          DEVELOP SCS UNIT HYDROGRAPH FOR SUB17
BA     1
LS     0      70
UD   6.6
KK SUB18          SUBAREA 18
KM          GENERATE SCS HYDROGRAPH FOR SUB18
BA  1.58
LS     0      70
UD   8.3
KK    J8
KM          ADD FOUR SUB AREAS AND KW FLOW
HC     5
KK  RCH8    ROUTE ADD KW
KM          ROUTE FLOW AND ADD KW CONTRIBUTION
BA   .72
UK   200     .25     .34     100
RK  1200     .12     .05     .05     TRAP       0       1
RK  3326    .018     .05             TRAP       8       2     YES
KK SUB19          SUBAREA 19
KM          GENERATE SCS UNIT HYDROGRAPH FOR SUB19
BA  1.96
LS     0      70
UD   7.4
KK    J9
KM          ADD SUB19
HC     2
KK RCH10          ROUTING
KM          ROUTE FROM RESERVOIR TO 11 ADDING KW COMPONENT
BA  2.78
UK   300     .28     .34     100
RK  3000      .2     .05     .05     TRAP       0       1
RK 13210    .012     .05             TRAP       8       2     YES
KK SUB23
KM          GENERATE SUB23 UNIT HYDROGRAPH
BA  2.54
LS     0      70
UD   7.6
KK SUB25
KM          GENERATE SCS UNIT HYDROGRAPH FOR SUB25
BA  1.75
LS     0      70
UD   6.5
KK   J11          ADD HYDROGRAPHS
```

```
KM          ADD 2 SUBS, 22 AND 25 TO ROUTED FLOW WITH KW ADDITION
HC     3
KK SUB21          SUB21
KM          GENERATE FOR SOUTH LA BARGE (SCS)
BA  6.65
LS     0      70
UD   8.1
KK SRCH1          ROUTE
KM          ROUTE RESERVIOR OUTFLOW
RK 20539    .019     .05     .05     TRAP       8       2      NO      15
KK SUB22
KM          GENERATE SUB22
BA  2.95
LS     0      70
UD   8.2
KK   J12          HYDROGRAPH ADDITION
KM          ADD SO LA BARGE ROUTED WITH SUB22
HC     3
KK RCH11          ROUTE
KM          ROUTE TO OUTLET
RK 10560    .011     .05     100     TRAP       8       2      NO      10
KK SUB24
KM          GENERATE SCS UNIT HYDROGRAPH FOR SUB24
BA  4.45
LS     0      70
UD  10.6
KK SUB26          SUB AREA 26
KM          GENERATE SCS UNIT HYDROGRAPH FOR SUB26
BA  4.33
LS     0      70
UD   9.9
KK SUB27
KM          GENERATE SCS UNIT HYDROGRAPH FOR SUB27
BA   2.3
LS     0      70
UD   8.7
KK   J13          JUNCTION 13
KM          COMBINE 1 MAIN AND 3 SUBS AT OUTLET
HC     4
ZZ
```

```
ID         LA BARGE SIMULATION ON HEC-1
ID         SIMULATION WITH 100 YEAR STORM WITH DAMS
ID         STREAM DRAINAGE NETWORK MODEL
*DIAGRAM
IT    15 15MAY92    0000      300
IO     3       0       0
KK  SUB1          HEADWATERS OF LA BARGE CREEK
KM         SCS RUNOFF COMPUTATION
BA  3.11
BF  -1.6       7    1.02
IN    60
PI   .05     .05     .05     .05     .05     .05     .32     .32     .32     .32
PI   .32     .32   .1133   .1133   .1133   .1133   .1133   .1133    .057    .057
PI  .057    .057    .057    .057
LS     0      70
UD  11.2
KK  RCH1
KM         ROUTE SUB1 TO JCT2 WITH KINEMATIC ADDITION
BA  1.74       0
UK   350     .34     .34     100
RK  2000     .24     .05      .1    TRAP       0
RK  7075    .011     .03            TRAP       8       2     YES
KK  SUB3          SCS UNIT GRAPH FROM SUB3
KM         RUNOFF FROM SUBAREA 3
BA  1.06
LS     0      70
UD   5.6
KK    J2          COMBINE SUB3 AT JCT2
KM         COMBINE ROUTED FLOW AND SUB3 AT JCT2
HC     2
KK  RCH2
KM         ROUTE COMBINED SUB1 SUB2 SUB3 TO JCT3 WITH KW ADDITION
BA   .32
UK   350     .27     .34     100
RK  1000      .1     .05     .05    TRAP       0       1
RK  4752    .014     .05            TRAP       6       2     YES
KK  SUB5          SUB5 UNIT SCS GRAPH
KM         HYDROGRAPH SCS FOR SUB5
BA  1.38
LS     0      70
UD   5.9
KK    J3
KM         ADD SUB5 TO ROUTED FLOW AT JCT3
HC     2
KK  RCH3          ROUTE AND KW COMBINE TO JCT4
KM         ADD KW TO FLOW AS ROUTE FROM 3 TO 4
BA   .54
UK   350     .28     .34     100
RK   200      .1     .05     .05    TRAP       0       1
RK  3801    .021     .05            TRAP       6       2     YES
```

```
KK  SUB7
KM          GENERATE SCS UH FOR SUB7
BA   1.8
LS     0      70
UD   7.5
KK  SUB8
KM          GENERATE HYDROGRAPH FOR SUB8
BA  1.38
LS     0      70
UD   6.6
KK    J4
KM          ADD SUB7 AND SUB8 TO ROUTED FLOW AT JCT4
HC     3
KK  RCH4          ROUTE TO JCT5 WITH KW ADDITION
KM          KINEMATIC ROUTE AND FLOW PLANE ADDITION
BA   .49
UK   200     .33     .34     100
RK   500      .2     .05     .05    TRAP       0       1
RK  8606   .0105     .05            TRAP       8       2     YES
KK SUB10          SUBAREA 10
KM          DEVELOP SCS UNIT HYDROGRAPH FOR SUB10
BA  3.37
LS     0      70
UD   9.1
KK    J5          ADD SUB10 AT JCT5
KM          ADD SUB10 TO ROUTED FLOW AT JCT5
HC     2
KK  RCH5          ROUTE AND ADD KW TO 6
KM          ROUTE 5 TO 6 AND ADD KW FLOW
BA   1.9
UK   250     .33     .34     100
RK  2000     .15     .05     .05    TRAP       0       1
RK 13094    .012     .05            TRAP       8       2     YES
KK SUB12          SUBAREA 12
KM          DEVELOP SCS UNIT HYDROGRAPH FOR SUB12
BA  2.86
LS     0      70
UD  10.5
KK    J6          ADD SUB12
KM          ADD SUB12 TO ROUTED FLOW AT JCT6
HC     2
KK    D7          UPPER DAM ON LA BARGE MAIN STEM
KM          RESERVOIR ROUTE FLOOD ACCUMULATED TO THIS POINT
RS     1    STOR  257.25
SV     0     .75       6   20.25      48   93.75     162  257.25     384  546.75
SE  8120    8125    8130    8135    8140    8145    8150    8155    8160    8165
SS  8155      40    2.54     1.5
SL8121.5      .1      .6     0.5
ST  8160     460     1.5     1.5
KK  RCH7          ROUTE AND ADD
```

```
KM          ROUTE DAM OUTFLOW AND ADD KW FROM 13
BA  1.01
UK   300     .18     .34     100
RK  2000     .10     .05     .05    TRAP       0       1
RK  3326    .001     .05            TRAP       8       2      YES
KK SUB14          SUBAREA 14
KM          DEVELOP SCS UNIT HYDROGRAPH FOR AREA 14
BA  1.52
LS     0      70
UD   4.4
KK SUB15          AREA 15
KM          DEVELOP SCS UNIT HYDROGRAPH FOR SUB15
BA   .46
LS     0      70
UD   4.9
KK SUB17          AREA 17
KM          DEVELOP SCS UNIT HYDROGRAPH FOR SUB17
BA     1
LS     0      70
UD   6.6
KK SUB18          SUBAREA 18
KM          GENERATE SCS HYDROGRAPH FOR SUB18
BA  1.58
LS     0      70
UD   8.3
KK    J8
KM          ADD FOUR SUB AREAS AND KW FLOW
HC     5
KK  RCH8    ROUTE ADD KW
KM          ROUTE FLOW AND ADD KW CONTRIBUTION
BA   .72
UK   200     .25     .34     100
RK  1200     .12     .05     .05    TRAP       0       1
RK  3326    .018     .05            TRAP       8       2      YES
KK SUB19          SUBAREA 19
KM          GENERATE SCS UNIT HYDROGRAPH FOR SUB19
BA  1.96
LS     0      70
UD   7.4
KK    J9
KM          ADD SUB19
HC     2
KK   D10          LOWER DAM ON LA BARGE MAIN
KM          ROUTE THROUGH LOWER DAM
RS     1    STOR  257.25
SV     0     1.1     8.8    29.7    70.4   137.5   237.6   377.3   563.2   801.9
SE  7960    7965    7970    7975    7980    7985    7990    7995    8000    8005
SS  7995      50    2.54     1.5
SL7961.5      .1      .6     0.5
ST  8000     650     1.5     1.5
```

```
KK RCH10        ROUTING
KM          ROUTE FROM RESERVOIR TO 11 ADDING KW COMPONENT
BA  2.78
UK   300     .28     .34     100
RK  3000      .2     .05     .05    TRAP      0      1
RK 13210    .012     .05            TRAP      8      2     YES
KK SUB23
KM          GENERATE SUB23 UNIT HYDROGRAPH
BA  2.54
LS     0      70
UD   7.6
KK SUB25
KM          GENERATE SCS UNIT HYDROGRAPH FOR SUB25
BA  1.75
LS     0      70
UD   6.5
KK   J11        ADD HYDROGRAPHS
KM          ADD 2 SUBS, 22 AND 25 TO ROUTED FLOW WITH KW ADDITION
HC     3
KK SUB21        SUB21
KM          GENERATE FOR SOUTH LA BARGE (SCS)
BA  6.65
LS     0      70
UD   8.1
KK    D3        DAM 3 ON SOUTH LA BARGE
KM          ROUTE FLOW GENERATED THROUGH RESERVOIR
RS     1    STOR   200.1
SV     0   .5833   4.666   15.75   37.33   72.91     126   200.1   298.7  425.25
SE  8240    8245    8250    8255    8260    8265    8270    8275    8280    8285
SS  8275      15    2.54     1.5
SL8241.5     0.1      .6     0.5
ST  8280     385     1.5     1.5
KK SRCH1        ROUTE
KM          ROUTE RESERVIOR OUTFLOW
RK 20539    .019     .05     .05    TRAP      8      2      NO      15
KK SUB22
KM          GENERATE SUB22
BA  2.95
LS     0      70
UD   8.2
KK   J12        HYDROGRAPH ADDITION
KM          ADD SO LA BARGE ROUTED WITH SUB22
HC     3
KK RCH11        ROUTE
KM          ROUTE TO OUTLET
RK 10560    .011     .05     100    TRAP      8      2      NO      10
KK SUB24
KM          GENERATE SCS UNIT HYDROGRAPH FOR SUB24
BA  4.45
LS     0      70
```

```
UD  10.6
KK SUB26          SUB AREA 26
KM          GENERATE SCS UNIT HYDROGRAPH FOR SUB26
BA  4.33
LS     0      70
UD   9.9
KK SUB27
KM          GENERATE SCS UNIT HYDROGRAPH FOR SUB27
BA   2.3
LS     0      70
UD   8.7
KK   J13          JUNCTION 13
KM          COMBINE 1 MAIN AND 3 SUBS AT OUTLET
HC     4
ZZ
```

```
ID         LA BARGE SIMULATION ON HEC-1
ID         SIMULATION WITH 100 YEAR STORM WITH DAMS
ID         STREAM DRAINAGE NETWORK MODEL
*DIAGRAM
IT    15 15MAY92    0000     300
IO     5       0       0
KK  SUB1          HEADWATERS OF LA BARGE CREEK
KM         SCS RUNOFF COMPUTATION
BA  3.11
BF  -1.6       7    1.02
IN    60
PI   .05     .05     .05     .05     .05     .05     .32     .32     .32     .32
PI   .32     .32   .1133   .1133   .1133   .1133   .1133   .1133    .057    .057
PI  .057    .057    .057    .057
LS     0      70
UD  11.2
KK  RCH1
KM         ROUTE SUB1 TO JCT2 WITH KINEMATIC ADDITION
BA  1.74       0
UK   350     .34     .34     100
RK  2000     .24     .05      .1    TRAP       0
RK  7075    .011     .03            TRAP       8       2     YES
KK  SUB3          SCS UNIT GRAPH FROM SUB3
KM         RUNOFF FROM SUBAREA 3
BA  1.06
LS     0      70
UD   5.6
KK    J2          COMBINE SUB3 AT JCT2
KM         COMBINE ROUTED FLOW AND SUB3 AT JCT2
HC     2
KK  RCH2
KM         ROUTE COMBINED SUB1 SUB2 SUB3 TO JCT3 WITH KW ADDITION
BA   .32
UK   350     .27     .34     100
RK  1000      .1     .05     .05    TRAP       0       1
RK  4752    .014     .05            TRAP       6       2     YES
KK  SUB5          SUB5 UNIT SCS GRAPH
KM         HYDROGRAPH SCS FOR SUB5
BA  1.38
LS     0      70
UD   5.9
KK    J3
KM         ADD SUB5 TO ROUTED FLOW AT JCT3
HC     2
KK  RCH3          ROUTE AND KW COMBINE TO JCT4
KM         ADD KW TO FLOW AS ROUTE FROM 3 TO 4
BA   .54
UK   350     .28     .34     100
RK   200      .1     .05     .05    TRAP       0       1
RK  3801    .021     .05            TRAP       6       2     YES
```

```
KK   SUB7
KM          GENERATE SCS UH FOR SUB7
BA   1.8
LS     0      70
UD   7.5
KK   SUB8
KM          GENERATE HYDROGRAPH FOR SUB8
BA  1.38
LS     0      70
UD   6.6
KK    J4
KM          ADD SUB7 AND SUB8 TO ROUTED FLOW AT JCT4
HC     3
KK   RCH4          ROUTE TO JCT5 WITH KW ADDITION
KM          KINEMATIC ROUTE AND FLOW PLANE ADDITION
BA   .49
UK   200     .33     .34     100
RK   500      .2     .05     .05     TRAP       0       1
RK  8606   .0105     .05             TRAP       8       2      YES
KK SUB10           SUBAREA 10
KM          DEVELOP SCS UNIT HYDROGRAPH FOR SUB10
BA  3.37
LS     0      70
UD   9.1
KK    J5           ADD SUB10 AT JCT5
KM          ADD SUB10 TO ROUTED FLOW AT JCT5
HC     2
KK   RCH5          ROUTE AND ADD KW TO 6
KM          ROUTE 5 TO 6 AND ADD KW FLOW
BA   1.9
UK   250     .33     .34     100
RK  2000     .15     .05     .05     TRAP       0       1
RK 13094    .012     .05             TRAP       8       2      YES
KK SUB12           SUBAREA 12
KM          DEVELOP SCS UNIT HYDROGRAPH FOR SUB12
BA  2.86
LS     0      70
UD  10.5
KK    J6           ADD SUB12
KM          ADD SUB12 TO ROUTED FLOW AT JCT6
HC     2
KK    D7           UPPER DAM ON LA BARGE MAIN STEM
KM          RESERVOIR ROUTE FLOOD ACCUMULATED TO THIS POINT
RS     1    STOR  257.25
SV     0     .75       6   20.25      48   93.75     162  257.25     384  546.75
SE  8120    8125    8130    8135    8140    8145    8150    8155    8160    8165
SS  8155      40    2.54     1.5
SL8121.5    7.07      .6     0.5
ST  8160     460     1.5     1.5
KK   RCH7          ROUTE AND ADD
```

```
KM          ROUTE DAM OUTFLOW AND ADD KW FROM 13
BA  1.01
UK   300     .18      .34      100
RK  2000     .10      .05      .05     TRAP       0        1
RK  3326    .001      .05              TRAP       8        2      YES
KK SUB14          SUBAREA 14
KM          DEVELOP SCS UNIT HYDROGRAPH FOR AREA 14
BA  1.52
LS     0      70
UD   4.4
KK SUB15          AREA 15
KM          DEVELOP SCS UNIT HYDROGRAPH FOR SUB15
BA   .46
LS     0      70
UD   4.9
KK SUB17          AREA 17
KM          DEVELOP SCS UNIT HYDROGRAPH FOR SUB17
BA     1
LS     0      70
UD   6.6
KK SUB18          SUBAREA 18
KM          GENERATE SCS HYDROGRAPH FOR SUB18
BA  1.58
LS     0      70
UD   8.3
KK    J8
KM          ADD FOUR SUB AREAS AND KW FLOW
HC     5
KK  RCH8    ROUTE ADD KW
KM          ROUTE FLOW AND ADD KW CONTRIBUTION
BA   .72
UK   200     .25      .34      100
RK  1200     .12      .05      .05     TRAP       0        1
RK  3326    .018      .05              TRAP       8        2      YES
KK SUB19          SUBAREA 19
KM          GENERATE SCS UNIT HYDROGRAPH FOR SUB19
BA  1.96
LS     0      70
UD   7.4
KK    J9
KM          ADD SUB19
HC     2
KK   D10          LOWER DAM ON LA BARGE MAIN
KM          ROUTE THROUGH LOWER DAM
RS     1    STOR  257.25
SV     0     1.1      8.8     29.7     70.4    137.5    237.6    377.3    563.2    801.9
SE  7960    7965     7970     7975     7980     7985     7990     7995     8000     8005
SS  7995      50     2.54      1.5
SL7961.5    7.07       .6      0.5
ST  8000     650      1.5      1.5
```

```
KK RCH10         ROUTING
KM          ROUTE FROM RESERVOIR TO 11 ADDING KW COMPONENT
BA  2.78
UK   300     .28      .34      100
RK  3000      .2      .05      .05     TRAP       0       1
RK 13210    .012      .05              TRAP       8       2     YES
KK SUB23
KM          GENERATE SUB23 UNIT HYDROGRAPH
BA  2.54
LS     0      70
UD   7.6
KK SUB25
KM          GENERATE SCS UNIT HYDROGRAPH FOR SUB25
BA  1.75
LS     0      70
UD   6.5
KK   J11         ADD HYDROGRAPHS
KM          ADD 2 SUBS, 22 AND 25 TO ROUTED FLOW WITH KW ADDITION
HC     3
KK SUB21         SUB21
KM          GENERATE FOR SOUTH LA BARGE (SCS)
BA  6.65
LS     0      70
UD   8.1
ID     D3         DAM 3 ON SOUTH LA BARGE
KM          ROUTE FLOW GENERATED THROUGH RESERVOIR
RS     1    STOR   200.1
SV     0   .5833   4.666   15.75   37.33   72.91     126   200.1   298.7  425.25
SE  8240    8245    8250    8255    8260    8265    8270    8275    8280    8285
SS  8275      16    2.54     1.5
SL8241.5    7.07      .6     0.5
ST  8280     384     1.5     1.5
KK SRCH1         ROUTE
KM          ROUTE RESERVIOR OUTFLOW
RK 20539    .019     .05     .05     TRAP       8       2      NO      15
KK SUB22
KM          GENERATE SUB22
BA  2.95
LS     0      70
UD   8.2
KK   J12         HYDROGRAPH ADDITION
KM          ADD SO LA BARGE ROUTED WITH SUB22
HC     3
KK RCH11         ROUTE
KM          ROUTE TO OUTLET
RK 10560    .011     .05     100     TRAP       8       2      NO      10
KK SUB24
KM          GENERATE SCS UNIT HYDROGRAPH FOR SUB24
BA  4.45
LS     0      70
```

```
UD  10.6
KK SUB26          SUB AREA 26
KM           GENERATE SCS UNIT HYDROGRAPH FOR SUB26
BA  4.33
LS     0     70
UD   9.9
KK SUB27
KM           GENERATE SCS UNIT HYDROGRAPH FOR SUB27
BA   2.3
LS     0     70
UD   8.7
KK   J13          JUNCTION 13
KM           COMBINE 1 MAIN AND 3 SUBS AT OUTLET
HC     4
ZZ
```

```
ID          LA BARGE SIMULATION ON HEC-1
ID          DAM BREACH SIMULATION
ID          STREAM DRAINAGE NETWORK MODEL
*DIAGRAM
IT    15 15MAY92    0000     300
IO     5      0        0
KK  SUB1            HEADWATERS OF LA BARGE CREEK
KM          SCS RUNOFF COMPUTATION
BA  3.11
BF  -1.6      7    1.02
PI   .01
LS     0     70
UD  11.2
KK  RCH1
KM          ROUTE SUB1 TO JCT2 WITH KINEMATIC ADDITION
BA  1.74      0
UK   350    .34      .34      100
RK  2000    .24      .05       .1     TRAP       0
RK  7075   .011      .03              TRAP       8        2      YES
KK  SUB3            SCS UNIT GRAPH FROM SUB3
KM          RUNOFF FROM SUBAREA 3
BA  1.06
LS     0     70
UD   5.6
KK    J2            COMBINE SUB3 AT JCT2
KM          COMBINE ROUTED FLOW AND SUB3 AT JCT2
HC     2
KK  RCH2
KM          ROUTE COMBINED SUB1 SUB2 SUB3 TO JCT3 WITH KW ADDITION
BA   .32
UK   350    .27      .34      100
RK  1000     .1      .05      .05     TRAP       0        1
RK  4752   .014      .05              TRAP       6        2      YES
KK  SUB5            SUB5 UNIT SCS GRAPH
KM          HYDROGRAPH SCS FOR SUB5
BA  1.38
LS     0     70
UD   5.9
KK    J3
KM          ADD SUB5 TO ROUTED FLOW AT JCT3
HC     2
KK  RCH3            ROUTE AND KW COMBINE TO JCT4
KM          ADD KW TO FLOW AS ROUTE FROM 3 TO 4
BA   .54
UK   350    .28      .34      100
RK   200     .1      .05      .05     TRAP       0        1
RK  3801   .021      .05              TRAP       6        2      YES
KK  SUB7
KM          GENERATE SCS UH FOR SUB7
BA   1.8
```

```
LS     0      70
UD   7.5
KK  SUB8
KM          GENERATE HYDROGRAPH FOR SUB8
BA  1.38
LS     0      70
UD   6.6
KK    J4
KM          ADD SUB7 AND SUB8 TO ROUTED FLOW AT JCT4
HC     3
KK  RCH4          ROUTE TO JCT5 WITH KW ADDITION
KM          KINEMATIC ROUTE AND FLOW PLANE ADDITION
BA   .49
UK   200     .33     .34     100
RK   500      .2     .05     .05    TRAP       0       1
RK  8606   .0105     .05            TRAP       8       2     YES
KK SUB10          SUBAREA 10
KM          DEVELOP SCS UNIT HYDROGRAPH FOR SUB10
BA  3.37
LS     0      70
UD   9.1
KK    J5          ADD SUB10 AT JCT5
KM          ADD SUB10 TO ROUTED FLOW AT JCT5
HC     2
KK  RCH5          ROUTE AND ADD KW TO 6
KM          ROUTE 5 TO 6 AND ADD KW FLOW
BA   1.9
UK   250     .33     .34     100
RK  2000     .15     .05     .05    TRAP       0       1
RK 13094    .012     .05            TRAP       8       2     YES
KK SUB12          SUBAREA 12
KM          DEVELOP SCS UNIT HYDROGRAPH FOR SUB12
BA  2.86
LS     0      70
UD  10.5
KK    J6          ADD SUB12
KM          ADD SUB12 TO ROUTED FLOW AT JCT6
HC     2
KK    D7          UPPER DAM ON LA BARGE MAIN STEM
KM          RESERVOIR ROUTE FLOOD ACCUMULATED TO THIS POINT
RS     1    STOR  257.25
SV     0     .75       6   20.25      48   93.75     162  257.25     384  546.75
SE  8120    8125    8130    8135    8140    8145    8150    8155    8160    8165
SS  8155      40    2.54     1.5
SL8121.5    7.07      .6     0.5
ST  8160     460     1.5     1.5
SB  8120      40       2     .25    8155
KK  RCH7          ROUTE AND ADD
KM          ROUTE DAM OUTFLOW AND ADD KW FROM 13
BA  1.01
```

```
UK   300      .18      .34      100
RK  2000      .10      .05      .05     TRAP        0        1
RK  3326     .001      .05              TRAP        8        2      YES
KK SUB14            SUBAREA 14
KM           DEVELOP SCS UNIT HYDROGRAPH FOR AREA 14
BA  1.52
LS     0       70
UD   4.4
KK SUB15            AREA 15
KM           DEVELOP SCS UNIT HYDROGRAPH FOR SUB15
BA   .46
LS     0       70
UD   4.9
KK SUB17            AREA 17
KM           DEVELOP SCS UNIT HYDROGRAPH FOR SUB17
BA     1
LS     0       70
UD   6.6
KK SUB18            SUBAREA 18
KM           GENERATE SCS HYDROGRAPH FOR SUB18
BA  1.58
LS     0       70
UD   8.3
KK    J8
KM           ADD FOUR SUB AREAS AND KW FLOW
HC     5
KK  RCH8     ROUTE ADD KW
KM           ROUTE FLOW AND ADD KW CONTRIBUTION
BA   .72
UK   200      .25      .34      100
RK  1200      .12      .05      .05     TRAP        0        1
RK  3326     .018      .05              TRAP        8        2      YES
KK SUB19            SUBAREA 19
KM           GENERATE SCS UNIT HYDROGRAPH FOR SUB19
BA  1.96
LS     0       70
UD   7.4
KK    J9
KM           ADD SUB19
HC     2
KK   D10            LOWER DAM ON LA BARGE MAIN
KM           ROUTE THROUGH LOWER DAM
RS     1     STOR   257.25
SV     0      1.1      8.8     29.7     70.4    137.5    237.6    377.3    563.2    801.9
SE  7960     7965     7970     7975     7980     7985     7990     7995     8000     8005
SS  7995       50     2.54      1.5
SL7961.5     7.07       .6      0.5
ST  8000      650      1.5      1.5
SB  7960       40        2      .25     7995
KK RCH10            ROUTING
```

```
KM         ROUTE FROM RESERVOIR TO 11 ADDING KW COMPONENT
BA  2.78
UK   300     .28     .34     100
RK  3000      .2     .05     .05    TRAP      0      1
RK 13210    .012     .05            TRAP      8      2      YES
KK SUB23
KM         GENERATE SUB23 UNIT HYDROGRAPH
BA  2.54
LS     0      70
UD   7.6
KK SUB25
KM         GENERATE SCS UNIT HYDROGRAPH FOR SUB25
BA  1.75
LS     0      70
UD   6.5
KK   J11         ADD HYDROGRAPHS
KM         ADD 2 SUBS, 22 AND 25 TO ROUTED FLOW WITH KW ADDITION
HC     3
KK SUB21         SUB21
KM         GENERATE FOR SOUTH LA BARGE (SCS)
BA  6.65
LS     0      70
UD   8.1
KK    D3         DAM 3 ON SOUTH LA BARGE
KM         ROUTE FLOW GENERATED THROUGH RESERVOIR
RS     1   STOR   200.1
SV     0  .5833   4.666   15.75   37.33   72.91    126   200.1   298.7  425.25
SE  8240   8245    8250    8255    8260    8265   8270    8275    8280    8285
SS  8275     16    2.54     1.5
SL8241.5   7.07      .6     0.5
ST  8280    384     1.5     1.5
SB  8240     40       2     .25    8275
KK SRCH1         ROUTE
KM         ROUTE RESERVIOR OUTFLOW
RK 20539   .019     .05     .05    TRAP      8      2      NO      15
KK SUB22
KM         GENERATE SUB22
BA  2.95
LS     0      70
UD   8.2
KK   J12         HYDROGRAPH ADDITION
KM         ADD SO LA BARGE ROUTED WITH SUB22
HC     3
KK RCH11         ROUTE
KM         ROUTE TO OUTLET
RK 10560   .011     .05     100    TRAP      8      2      NO      10
KK SUB24
KM         GENERATE SCS UNIT HYDROGRAPH FOR SUB24
BA  4.45
LS     0      70
```

```
UD  10.6
KK SUB26        SUB AREA 26
KM          GENERATE SCS UNIT HYDROGRAPH FOR SUB26
BA  4.33
LS     0     70
UD   9.9
KK SUB27
KM          GENERATE SCS UNIT HYDROGRAPH FOR SUB27
BA   2.3
LS     0     70
UD   8.7
KK   J13        JUNCTION 13
KM          COMBINE 1 MAIN AND 3 SUBS AT OUTLET
HC     4
ZZ
```

Gooseberry Creek Input Data

```
ID          GOOSEBERRY CREEK 100 YEAR FLOOD SIMULATION
ID          AMCII CONDITIONS
ID          SMALL STORAGE PROJECT THESIS
*DIAGRAM
IT    15  5MAY92    0000
IO     3       0       0
KK  SUB1       SUBAREA 1
KM       GENERATE SCS HYDROGRAPH FOR SUBAREA 1
BA  20.6
PI   .02     .02     .05     .05     .25     .28     .30     .28     .13     .13
PI    .1      .1     .04     .04     .03     .03     .02     .02     .02     .02
PI   .01     .01     .01     .01
LS     0      65
UD 15.59
KK  RCH1          REACH 1
KM          ROUTE SUBAREA 1 THROUGH REACH 1
RK 22862    .017     .05            TRAP       1       2
KK  SUB2          SUBAREA 2
KM          GENERATE HYDROGRAPH FOR SUBAREA 2
BA  11.2
LS     0      65
UD 11.83
KK    J2          JUNCTION 1
KM          COMBINE AT JUNCTION 2
HC     2
KK  RCH2          REACH 2
KM          ROUTE FLOW THROUGH REACH 2
RK 15840    .015     .05            TRAP       2       2
KK  SUB3          SUBAREA 3
KM          GENERATE SUBAREA 3 SCS HYDROGRAPH
BA   7.9
LS     0      65
UD 11.93
KK    J3          JUNCTION 3
KM          COMBINE AT JUNCTION 3
HC     2
KK  RCH4          REACH 4
KM          ROUTE FLOW THROUGH REACH 4
RK 19536     .01    .035            TRAP       3       2
KK  SUB4          SUBAREA 4
KM          GENERATE SCS HYDROGRAPH FOR SUBAREA 4
BA  11.5
LS     0      65
UD 10.36
KK    J4          JUNCTION 4
KM          ADD FLOWS AT JUNCTION 4
HC     2
KK  RCH5          REACH 5
KM            ROUTE FLOWS THROUGH REACH 5
RK 44352   .0072    .035            TRAP       4       2
```

```
KK  SUB5          SUBAREA 5
KM          GENERATE SCS HYDROGRAPH FOR SUBAREA 5
BA 14.27
LS     0     78
UD 14.33
KK    J5          JUNCTION 5
KM          COMBINE FLOWS AT JUNCTION 5
HC     2
KK  RCH6          REACH 6
KM          ROUTE FLOWS THROUGH REACH 6
RK 23760   .0067    .035            TRAP       5       2
KK  SUB6          SUBAREA 6
KM          GENERATE SCS HYDROGRAPH FOR SUBAREA 6
BA   6.1
LS     0     78
UD  7.00
KK    J6          JUNCTION 6
KM          ADD FLOWS AT JUNCTION 6
HC     2
ZZ
```

```
ID          GOOSEBERRY CREEK 100 YEAR FLOOD SIMULATION
ID          DAMS ON SYSTEM AMCII CONDITIONS OUTLET PLUGGED
ID          SMALL STORAGE PROJECT THESIS
*DIAGRAM
IT    15  5MAY92    0000
IO     3       0       0
KK  SUB1       SUBAREA 1
KM       GENERATE SCS HYDROGRAPH FOR SUBAREA 1
BA  20.6
PI   .02     .02     .05     .05     .25     .28     .30     .28     .13     .13
PI    .1      .1     .04     .04     .03     .03     .02     .02     .02     .02
PI   .01     .01     .01     .01
LS     0      65
UD 15.59
KK  RCH1          REACH 1
KM          ROUTE SUBAREA 1 THROUGH REACH 1
RK 22862    .017     .05            TRAP       1       2
KK  SUB2          SUBAREA 2
KM          GENERATE HYDROGRAPH FOR SUBAREA 2
BA  11.2
LS     0      65
UD 11.83
KK    J2          JUNCTION 1
KM          COMBINE AT JUNCTION 2
HC     2
KK  RCH2          REACH 2
KM          ROUTE FLOW THROUGH REACH 2
RK 15840    .015     .05            TRAP       2       2
KK  SUB3          SUBAREA 3
KM          GENERATE SUBAREA 3 SCS HYDROGRAPH
BA   7.9
LS     0      65
UD 11.93
KK    J3          JUNCTION 3
KM          COMBINE AT JUNCTION 3
HC     2
KK  RCH4          REACH 4
KM          ROUTE FLOW THROUGH REACH 4
RK 19536     .01    .035            TRAP       3       2
KK  SUB4          SUBAREA 4
KM          GENERATE SCS HYDROGRAPH FOR SUBAREA 4
BA  11.5
LS     0      65
UD 10.36
KK    J4          JUNCTION 4
KM          ADD FLOWS AT JUNCTION 4
HC     2
KK    D1          DAM 1
KM          ROUTE FLOW THROUGH DAM 1
RS     1    STOR     343
```

```
SV     0      1      8     27     64    125    216    343    512    729
SE  6280   6285   6290   6295   6300   6305   6310   6315   6320   6325
SS  6315     15   2.54    1.5
SL6281.5    .01     .6     .5
ST  6320    585    1.5    1.5
KK  RCH5          REACH 5
KM            ROUTE FLOWS THROUGH REACH 5
RK 44352  .0072   .035           TRAP      4      2
KK  SUB5          SUBAREA 5
KM          GENERATE SCS HYDROGRAPH FOR SUBAREA 5
BA 14.27
LS     0     78
UD 14.33
KK    J5          JUNCTION 5
KM          COMBINE FLOWS AT JUNCTION 5
HC     2
KK    D2          DAM 2
KM          ROUTE FLOW THROUGH DAM 2
RS     1    STOR  571.7
SV     0   1.67  13.33     45  106.7  208.3    360  571.7  853.3   1215
SE  5960   5965   5970   5975   5980   5985   5990   5995   6000   6005
SS  5995     18   2.54    1.5
SL5961.5    .01     .6     .5
ST  6000    982    1.5    1.5
KK  RCH6          REACH 6
KM          ROUTE FLOWS THROUGH REACH 6
RK 23760  .0067   .035           TRAP      5      2
KK  SUB6          SUBAREA 6
KM          GENERATE SCS HYDROGRAPH FOR SUBAREA 6
BA   6.1
LS     0     78
UD  7.00
KK    J6          JUNCTION 6
KM          ADD FLOWS AT JUNCTION 6
HC     2
KK    D3          DAM 3
KM       ROUTE THROUGH DAM 3
RS     1    STOR  520.2
SV     0   1.52  12.13  40.95   97.1  189.6  327.6  520.2  776.5 1105.6
SE  5800   5805   5810   5815   5820   5825   5830   5835   5840   5845
SS  5835     20   2.54    1.5
SL5801.5    .01     .6     .5
ST  5840    980    1.5    1.5
KK  RCH7          REACH 7
KM          ROUTE FLOW THROUGH REACH 7
RK 30000  .0067    .03
ZZ
```

```
ID          GOOSEBERRY CREEK 100 YEAR FLOOD SIMULATION
ID          DAMS ON SYSTEM AMCII CONDITIONS
ID          SMALL STORAGE PROJECT THESIS
*DIAGRAM
IT    15  5MAY92    0000
IO     3       0       0
KK  SUB1       SUBAREA 1
KM       GENERATE SCS HYDROGRAPH FOR SUBAREA 1
BA  20.6
PI   .02     .02     .05     .05     .25     .28     .30     .28     .13     .13
PI    .1      .1     .04     .04     .03     .03     .02     .02     .02     .02
PI   .01     .01     .01     .01
LS     0      65
UD 15.59
KK  RCH1          REACH 1
KM          ROUTE SUBAREA 1 THROUGH REACH 1
RK 22862    .017     .05            TRAP       1       2
KK  SUB2          SUBAREA 2
KM          GENERATE HYDROGRAPH FOR SUBAREA 2
BA  11.2
LS     0      65
UD 11.83
KK    J2          JUNCTION 1
KM          COMBINE AT JUNCTION 2
HC     2
KK  RCH2          REACH 2
KM          ROUTE FLOW THROUGH REACH 2
RK 15840    .015     .05            TRAP       2       2
KK  SUB3          SUBAREA 3
KM          GENERATE SUBAREA 3 SCS HYDROGRAPH
BA   7.9
LS     0      65
UD 11.93
KK    J3          JUNCTION 3
KM          COMBINE AT JUNCTION 3
HC     2
KK  RCH4          REACH 4
KM          ROUTE FLOW THROUGH REACH 4
RK 19536     .01    .035            TRAP       3       2
KK  SUB4          SUBAREA 4
KM          GENERATE SCS HYDROGRAPH FOR SUBAREA 4
BA  11.5
LS     0      65
UD 10.36
KK    J4          JUNCTION 4
KM          ADD FLOWS AT JUNCTION 4
HC     2
KK    D1          DAM 1
KM          ROUTE FLOW THROUGH DAM 1
RS     1    STOR      343
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```
SV     0      1      8     27     64    125    216    343    512    729
SE  6280   6285   6290   6295   6300   6305   6310   6315   6320   6325
SS  6315     15   2.54    1.5
SL6281.5   7.07     .6     .5
ST  6320    585    1.5    1.5
KK  RCH5          REACH 5
KM              ROUTE FLOWS THROUGH REACH 5
RK 44352  .0072   .035           TRAP      4      2
KK  SUB5          SUBAREA 5
KM            GENERATE SCS HYDROGRAPH FOR SUBAREA 5
BA 14.27
LS     0     78
UD 14.33
KK    J5          JUNCTION 5
KM            COMBINE FLOWS AT JUNCTION 5
HC     2
KK    D2          DAM 2
KM            ROUTE FLOW THROUGH DAM 2
RS     1   STOR  571.7
SV     0   1.67  13.33     45  106.7  208.3    360  571.7  853.3   1215
SE  5960   5965   5970   5975   5980   5985   5990   5995   6000   6005
SS  5995     18   2.54    1.5
SL5961.5   7.07     .6     .5
ST  6000    982    1.5    1.5
KK  RCH6          REACH 6
KM            ROUTE FLOWS THROUGH REACH 6
RK 23760  .0067   .035           TRAP      5      2
KK  SUB6          SUBAREA 6
KM            GENERATE SCS HYDROGRAPH FOR SUBAREA 6
BA   6.1
LS     0     78
UD  7.00
KK    J6          JUNCTION 6
KM            ADD FLOWS AT JUNCTION 6
HC     2
KK    D3          DAM 3
KM         ROUTE THROUGH DAM 3
RS     1   STOR  520.2
SV     0   1.52  12.13  40.95   97.1  189.6  327.6  520.2  776.5 1105.6
SE  5800   5805   5810   5815   5820   5825   5830   5835   5840   5845
SS  5835     20   2.54    1.5
SL5801.5   7.07     .6     .5
ST  5840    980    1.5    1.5
KK  RCH7          REACH 7
KM            ROUTE FLOW THROUGH REACH 7
RK 30000  .0067    .03
ZZ
```

```
ID          GOOSEBERRY CREEK 100 YEAR FLOOD SIMULATION
ID          CLEARWEATHER BREACH OF SYSTEM DAMS
ID          SMALL STORAGE PROJECT THESIS
*DIAGRAM
IT    15  5MAY92    0000
IO     3       0       0
KK  SUB1       SUBAREA 1
KM       GENERATE SCS HYDROGRAPH FOR SUBAREA 1
BA  20.6
BF   -.1       5     1.1
PI   .01
LS     0      65
UD 15.59
KK  RCH1          REACH 1
KM          ROUTE SUBAREA 1 THROUGH REACH 1
RK 22862    .017      .05          TRAP       1       2
KK  SUB2          SUBAREA 2
KM          GENERATE HYDROGRAPH FOR SUBAREA 2
BA  11.2
LS     0      65
UD 11.83
KK    J2          JUNCTION 1
KM          COMBINE AT JUNCTION 2
HC     2
KK  RCH2          REACH 2
KM          ROUTE FLOW THROUGH REACH 2
RK 15840    .015      .05          TRAP       2       2
KK  SUB3          SUBAREA 3
KM          GENERATE SUBAREA 3 SCS HYDROGRAPH
BA   7.9
LS     0      65
UD 11.93
KK    J3          JUNCTION 3
KM          COMBINE AT JUNCTION 3
HC     2
KK  RCH4          REACH 4
KM          ROUTE FLOW THROUGH REACH 4
RK 19536     .01     .035          TRAP       3       2
KK  SUB4          SUBAREA 4
KM          GENERATE SCS HYDROGRAPH FOR SUBAREA 4
BA  11.5
LS     0      65
UD 10.36
KK    J4          JUNCTION 4
KM          ADD FLOWS AT JUNCTION 4
HC     2
KK    D1          DAM 1
KM          ROUTE FLOW THROUGH DAM 1
RS     1    STOR      343
SV     0       1       8      27      64     125     216     343     512     729
```

```
SE  6280    6285    6290    6295    6300    6305    6310    6315    6320    6325
SS  6315      15    2.54     1.5
SL6281.5    7.07      .6      .5
ST  6320     585     1.5     1.5
SB  6280      40       2     .25    6315
KK  RCH5          REACH 5
KM              ROUTE FLOWS THROUGH REACH 5
RK 44352   .0072    .035            TRAP       4       2
KK  SUB5            SUBAREA 5
KM            GENERATE SCS HYDROGRAPH FOR SUBAREA 5
BA 14.27
LS     0      78
UD 14.33
KK    J5            JUNCTION 5
KM            COMBINE FLOWS AT JUNCTION 5
HC     2
KK    D2            DAM 2
KM            ROUTE FLOW THROUGH DAM 2
RS     1      STOR   571.7
SV     0      1.67   13.33      45   106.7   208.3     360   571.7   853.3    1215
SE  5960      5965    5970    5975    5980    5985    5990    5995    6000    6005
SS  5995        18    2.54     1.5
SL5961.5      7.07      .6      .5
ST  6000       982     1.5     1.5
SB  5960        40       2     .25    5995
KK  RCH6            REACH 6
KM            ROUTE FLOWS THROUGH REACH 6
RK 23760    .0067    .035            TRAP       5       2
KK  SUB6            SUBAREA 6
KM            GENERATE SCS HYDROGRAPH FOR SUBAREA 6
BA   6.1
LS     0        78
UD  7.00
KK    J6            JUNCTION 6
KM            ADD FLOWS AT JUNCTION 6
HC     2
KK    D3            DAM 3
KM         ROUTE THROUGH DAM 3
RS     1      STOR   520.2
SV     0      1.52   12.13   40.95    97.1   189.6   327.6   520.2   776.5  1105.6
SE  5800      5805    5810    5815    5820    5825    5830    5835    5840    5845
SS  5835        20    2.54     1.5
SL5801.5      7.07      .6      .5
ST  5840       980     1.5     1.5
SB  5800        40       2     .25    5835
KK  RCH7            REACH 7
KM            ROUTE FLOW THROUGH REACH 7
RK 30000     .0067     .03
ZZ
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Inyan Kara Creek Data

```
ID          INYAN KARA CREEK MODEL FOR SMALL STORAGE PROJECTS
ID          100 YEAR FLOOD SIMULATION AMCIII CONDITIONS
ID          FOR THE WYOMING WATER DEVELOPMENT COMMISSION
*DIAGRAM
IT    15 15MAY92    0000     300
IO     3       0       0
KK  SUB1          SUBAREA 1 INYAN KARA
KM          GENERATE SCS HYDROGRAPH FOR INYAN KARA SUB 1
BA    18
PI   .02     .02     .05     .05     .27      .3     .32      .3     .14     .14
PI    .1      .1     .04     .04     .03     .03     .02     .02     .02     .02
PI   .01     .01     .01     .01
LS     0      84
UD 17.21
KK  RCH1          ROUTE REACH 1
KM          ROUTE SUB1 THROUGH REACH1
RK 50635    .025     .03             TRAP       1       2
KK  SUB2
KM          DEVELOP SCS HYDROGRAPH FOR SUB2
BA  13.6
LS     0      84
UD 15.76
KK    J2
KM          ADD SUB1 ROUTED TO SUB2 AT JUNCTION2
HC     2
KK  RCH2
KM          ROUTE TO J3
RK 41184   .0034     .03             TRAP       1       2
KK  SUB3
KM          DEVELOP SCS HYDROGRAPH FOR SUB3
BA  11.2
LS     0      84
UD  13.3
KK    J3          JUNCTION 3
KM          ADD HYDROGRAPHS AT J3
HC     2
KK  SUB4          SUBAREA 4
KM          DEVELOP SCS HYDROGRAPH FOR SUBAREA 4
BA  18.3
LS     0      84
UD  16.5
KK  RCH4          REACH 4
KM          ROUTE INYAN KARA TO J5
RK 12672    .004     .03             TRAP       1       2
KK  SUB5          SUBAREA 5
KM          DEVELOP SCS HYDROGRAPH FOR SUBAREA 5
LS     0      84
UD  6.94
KK    J5          JUNCTION 5
KM          ADD FLOWS AT J5
```

```
HC     3
KK  RCH6         REACH 6
KM          ROUTE COMBINED FLOWS TO J5
RK 15840   .0082     .03             TRAP       2       2
KK  SUB6         SUBAREA 6
KM          DEVELOP SCS HYDROGRAPH FOR SUBAREA 5
BA  6.99
LS     0     84
UD  7.66
KK    J6         JUNCTION 6
KM          ADD HYDROGRAPHS AT JUNCTION 6
HC     2
KK  RCH7         REACH 7
KM          ROUTE FLOWS THROUGH REACH 7
RK  6336   .0039     .03             TRAP       4       2
KK  SUB7         SUBAREA 7
KM          GENERATE SCS HYDROGRAPH FOR SUBAREA 7
BA   8.2
LS     0     84
UD  3.68
KK  JCT7         JUNCTION 7
KM          COMBINE FLOWS AT JUNCTION 7
HC     2
KK  RCH8         REACH 8
KM          ROUTE OUT OF THE STUDY AREA
RK 20000   .0039     .03             TRAP       4       2
ZZ
```

```
ID         INYAN KARA CREEK MODEL FOR SMALL STORAGE PROJECTS
ID         AMCIII CONDITIONS AND DAMS ON SYSTEM
ID         FOR THE WYOMING WATER DEVELOPMENT COMMISSION
*DIAGRAM
IT    15 15MAY92    0000     300
IO     3       0       0
KK  SUB1          SUBAREA 1 INYAN KARA
KM         GENERATE SCS HYDROGRAPH FOR INYAN KARA SUB 1
BA    18
PI   .02     .02     .05     .05     .27      .3     .32      .3     .14     .14
PI    .1      .1     .04     .04     .03     .03     .02     .02     .02     .02
PI   .01     .01     .01     .01
LS     0      84
UD 17.21
KK  RCH1          ROUTE REACH 1
KM         ROUTE SUB1 THROUGH REACH1
RK 50635   .025     .03             TRAP       1       2
KK  SUB2
KM         DEVELOP SCS HYDROGRAPH FOR SUB2
BA  13.6
LS     0      84
UD 15.76
KK    J2
KM         ADD SUB1 ROUTED TO SUB2 AT JUNCTION2
HC     2
KK  RCH2
KM         ROUTE TO J3
RK 41184  .0034     .03             TRAP       1       2
KK  SUB3
KM         DEVELOP SCS HYDROGRAPH FOR SUB3
BA  11.2
LS     0      84
UD  13.3
KK    J3          JUNCTION 3
KM         ADD HYDROGRAPHS AT J3
HC     2
KK  SUB4          SUBAREA 4
KM         DEVELOP SCS HYDROGRAPH FOR SUBAREA 4
BA  18.3
LS     0      84
UD  16.5
KK    D1          DAM 1
KM         ROUTE FLOW THROUGH DAM 1
RS     1   STOR   571.7
SV     0   1.67    13.3      45   106.7   208.3     360   571.7   853.3    1215
SE  5100   5105    5110    5115    5120    5125    5130    5135    5140    5145
SS  5135     22    2.54     1.5
SL5101.5    0.1      .6      .5
ST  5140    578     1.5     1.5
KK  RCH4          REACH 4
```

```
KM          ROUTE INYAN KARA TO J5
RK 12672    .004     .03           TRAP      1       2
KK  SUB5          SUBAREA 5
KM          DEVELOP SCS HYDROGRAPH FOR SUBAREA 5
LS     0      84
UD  6.94
KK    J5          JUNCTION 5
KM          ADD FLOWS AT J5
HC     3
KK  RCH6          REACH 6
KM          ROUTE COMBINED FLOWS TO J5
RK 15840   .0082     .03           TRAP      2       2
KK  SUB6          SUBAREA 6
KM          DEVELOP SCS HYDROGRAPH FOR SUBAREA 5
BA  6.99
LS     0      84
UD  7.66
KK    J6          JUNCTION 6
KM          ADD HYDROGRAPHS AT JUNCTION 6
HC     2
KK    D2          DAM 2
KM          ROUTE FLOW THROUGH DAM 2
RS     1    STOR   628.8
SV     0    1.83   14.67    49.5  117.33   229.2     396   628.8   938.7  1336.5
SE  4960    4965    4970    4975    4980    4985    4990    4995    5000    5005
SS  4995     105    2.54     1.5
SL4961.5     .01      .6      .5
ST  5000     295     1.5     1.5
KK  RCH7          REACH 7
KM          ROUTE FLOWS THROUGH REACH 7
RK  6336   .0039     .03           TRAP      4       2
KK  SUB7          SUBAREA 7
KM          GENERATE SCS HYDROGRAPH FOR SUBAREA 7
BA   8.2
LS     0      84
UD  3.68
KK  JCT7          JUNCTION 7
KM          COMBINE FLOWS AT JUNCTION 7
HC     2
KK    D3          DAM 3 LOWER INYAN KARA
KM          RESERVOIR ROUTE FLOW THROUGH LOWER RESERVOIR
RS     1    STOR     343
SV     0       1       8      27      64     125     216     343     512     729
SE  4895    4900    4905    4910    4915    4920    4925    4930    4935    4940
SS  4930     110    2.54     1.5
SL4896.5     .01      .6      .5
ST  4935      90     1.5     1.5
KK  RCH8          REACH 8 ROUTE
KM          ROUTE FLOW OUT OF DAM
RK 30000     .04     .03           TRAP      4       2
```

ZZ

```
ID          INYAN KARA CREEK MODEL FOR SMALL STORAGE PROJECTS
ID          AMCIII CONDITIONS AND DAMS ON SYSTEM
ID          FOR THE WYOMING WATER DEVELOPMENT COMMISSION
*DIAGRAM
IT    15 15MAY92    0000     300
IO     3       0       0
KK  SUB1          SUBAREA 1 INYAN KARA
KM          GENERATE SCS HYDROGRAPH FOR INYAN KARA SUB 1
BA    18
PI   .02     .02     .05     .05     .27      .3     .32      .3     .14     .14
PI    .1      .1     .04     .04     .03     .03     .02     .02     .02     .02
PI   .01     .01     .01     .01
LS     0      84
UD 17.21
KK  RCH1          ROUTE REACH 1
KM          ROUTE SUB1 THROUGH REACH1
RK 50635    .025     .03            TRAP       1       2
KK  SUB2
KM          DEVELOP SCS HYDROGRAPH FOR SUB2
BA  13.6
LS     0      84
UD 15.76
KK    J2
KM          ADD SUB1 ROUTED TO SUB2 AT JUNCTION2
HC     2
KK  RCH2
KM          ROUTE TO J3
RK 41184   .0034     .03            TRAP       1       2
KK  SUB3
KM          DEVELOP SCS HYDROGRAPH FOR SUB3
BA  11.2
LS     0      84
UD  13.3
KK    J3          JUNCTION 3
KM          ADD HYDROGRAPHS AT J3
HC     2
KK  SUB4          SUBAREA 4
KM          DEVELOP SCS HYDROGRAPH FOR SUBAREA 4
BA  18.3
LS     0      84
UD  16.5
KK    D1          DAM 1
KM          ROUTE FLOW THROUGH DAM 1
RS     1    STOR   571.7
SV     0    1.67    13.3      45   106.7   208.3     360   571.7   853.3    1215
SE  5100    5105    5110    5115    5120    5125    5130    5135    5140    5145
SS  5135      22    2.54     1.5
SL5101.5    7.07      .6      .5
ST  5140     578     1.5     1.5
KK  RCH4          REACH 4
```

```
KM          ROUTE INYAN KARA TO J5
RK 12672    .004     .03             TRAP       1       2
KK  SUB5          SUBAREA 5
KM          DEVELOP SCS HYDROGRAPH FOR SUBAREA 5
LS     0      84
UD  6.94
KK    J5          JUNCTION 5
KM          ADD FLOWS AT J5
HC     3
KK  RCH6          REACH 6
KM          ROUTE COMBINED FLOWS TO J5
RK 15840   .0082     .03             TRAP       2       2
KK  SUB6          SUBAREA 6
KM          DEVELOP SCS HYDROGRAPH FOR SUBAREA 5
BA  6.99
LS     0      84
UD  7.66
KK    J6          JUNCTION 6
KM          ADD HYDROGRAPHS AT JUNCTION 6
HC     2
KK    D2          DAM 2
KM          ROUTE FLOW THROUGH DAM 2
RS     1    STOR   628.8
SV     0    1.83   14.67    49.5  117.33   229.2     396   628.8   938.7  1336.5
SE  4960    4965    4970    4975    4980    4985    4990    4995    5000    5005
SS  4995     105    2.54     1.5
SL4961.5    7.07      .6      .5
ST  5000     295     1.5     1.5
KK  RCH7          REACH 7
KM          ROUTE FLOWS THROUGH REACH 7
RK  6336   .0039     .03             TRAP       4       2
KK  SUB7          SUBAREA 7
KM          GENERATE SCS HYDROGRAPH FOR SUBAREA 7
BA   8.2
LS     0      84
UD  3.68
KK  JCT7          JUNCTION 7
KM          COMBINE FLOWS AT JUNCTION 7
HC     2
KK    D3          DAM 3 LOWER INYAN KARA
KM          RESERVOIR ROUTE FLOW THROUGH LOWER RESERVOIR
RS     1    STOR     343
SV     0       1       8      27      64     125     216     343     512     729
SE  4895    4900    4905    4910    4915    4920    4925    4930    4935    4940
SS  4930     110    2.54     1.5
SL4896.5    7.07      .6      .5
ST  4935      90     1.5     1.5
KK  RCH8          REACH 8 ROUTE
KM          ROUTE FLOW OUT OF DAM
RK 30000     .04     .03             TRAP       4       2
```

ZZ

```
ID          INYAN KARA CREEK MODEL FOR SMALL STORAGE PROJECTS
ID          BREACH SYSTEM DAMS ON INYAN KARA
ID          FOR THE WYOMING WATER DEVELOPMENT COMMISSION
*DIAGRAM
IT    15 15MAY92    0000      300
IO     3       0        0
KK  SUB1          SUBAREA 1 INYAN KARA
KM          GENERATE SCS HYDROGRAPH FOR INYAN KARA SUB 1
BA    18
BF   -.1       2     1.02
PI   .01
LS     0      84
UD 17.21
KK  RCH1          ROUTE REACH 1
KM          ROUTE SUB1 THROUGH REACH1
RK 50635    .025      .03            TRAP       1       2
KK  SUB2
KM          DEVELOP SCS HYDROGRAPH FOR SUB2
BA  13.6
LS     0      84
UD 15.76
KK    J2
KM          ADD SUB1 ROUTED TO SUB2 AT JUNCTION2
HC     2
KK  RCH2
KM          ROUTE TO J3
RK 41184   .0034      .03            TRAP       1       2
KK  SUB3
KM          DEVELOP SCS HYDROGRAPH FOR SUB3
BA  11.2
LS     0      84
UD  13.3
KK    J3          JUNCTION 3
KM          ADD HYDROGRAPHS AT J3
HC     2
KK  SUB4          SUBAREA 4
KM          DEVELOP SCS HYDROGRAPH FOR SUBAREA 4
BA  18.3
LS     0      84
UD  16.5
KK    D1          DAM 1
KM          ROUTE FLOW THROUGH DAM 1
RS     1    STOR   571.7
SV     0    1.67    13.3      45   106.7   208.3     360   571.7   853.3    1215
SE  5100    5105    5110    5115    5120    5125    5130    5135    5140    5145
SS  5135      22    2.54     1.5
SL5101.5    7.07      .6      .5
ST  5140     578     1.5     1.5
SB  5100      40       2     .25    5135
KK  RCH4          REACH 4
```

```
KM          ROUTE INYAN KARA TO J5
RK 12672    .004      .03             TRAP       1        2
KK  SUB5          SUBAREA 5
KM          DEVELOP SCS HYDROGRAPH FOR SUBAREA 5
LS     0      84
UD  6.94
KK    J5          JUNCTION 5
KM          ADD FLOWS AT J5
HC     3
KK  RCH6          REACH 6
KM          ROUTE COMBINED FLOWS TO J5
RK 15840   .0082      .03             TRAP       2        2
KK  SUB6          SUBAREA 6
KM          DEVELOP SCS HYDROGRAPH FOR SUBAREA 5
BA  6.99
LS     0      84
UD  7.66
KK    J6          JUNCTION 6
KM          ADD HYDROGRAPHS AT JUNCTION 6
HC     2
KK    D2          DAM 2
KM          ROUTE FLOW THROUGH DAM 2
RS     1    STOR   628.8
SV     0    1.83   14.67    49.5  117.33   229.2     396   628.8   938.7  1336.5
SE  4960    4965    4970    4975    4980    4985    4990    4995    5000    5005
SS  4995     105    2.54     1.5
SL4961.5    7.07      .6      .5
ST  5000     295     1.5     1.5
SB  4960      40       2     .25    4995
KK  RCH7          REACH 7
KM          ROUTE FLOWS THROUGH REACH 7
RK  6336   .0039     .03             TRAP       4        2
KK  SUB7          SUBAREA 7
KM          GENERATE SCS HYDROGRAPH FOR SUBAREA 7
BA   8.2
LS     0      84
UD  3.68
KK  JCT7          JUNCTION 7
KM          COMBINE FLOWS AT JUNCTION 7
HC     2
KK    D3          DAM 3 LOWER INYAN KARA
KM          RESERVOIR ROUTE FLOW THROUGH LOWER RESERVOIR
RS     1    STOR     343
SV     0       1       8      27      64     125     216     343     512     729
SE  4895    4900    4905    4910    4915    4920    4925    4930    4935    4940
SS  4930     110    2.54     1.5
SL4896.5    7.07      .6      .5
ST  4935      90     1.5     1.5
SB  4895      40       2     .25    4930
KK  RCH8          REACH 8 ROUTE
```

```
KM          ROUTE FLOW OUT OF DAM
RK 30000     .04      .03            TRAP       4        2
ZZ
```

APPENDIX B
HECWRC Input Data

La Barge Creek Data

```
TT  LA BARGE MEADOWS GUARD STATION (092080)
TT  DRAINAGE AREA 6.30 SQMI
TT  RECORD IS NOT CONTINUOUS IN THE WAR YEARS
TT  0 NON CONTRIBUTING; LINCOLN COUNTY
TT  DISCONTINUED 1981 BEGAN 1941
ID  2080  LABARGE AT THE MEADOWS
GS  2080              -.3
QR  208005001941       78
QR  208005001942       83
QR  208005001951      158
QR  208005001952       86
QR  208006001953      120
QR  208005001954      113
QR  208005001955       81
QR  208506001956      160
QR  208506001957      137
QR  208506001958      115
QR  208506001959       96
QR  208506001960       69
QR  208505001961       74
QR  208506001962      118
QR  208506001963       88
QR  208506001964      153
QR  208506001965      146
QR  208505001966       65
QR  208506001967      121
QR  208506001968      120
QR  208505001969       87
QR  208506001970      105
QR  208506001971      166
QR  208506001972      161
QR  208506001973       73
QR  208506001974      137
QR  208507001975      112
QR  208505001976       96
QR  208504001977       21
QR  208506001978      142
QR  208505001979      104
QR  208506001980       84
QR  208505001981       58
QR  208504001977       21
QR  208506001978      142
QR  208505281979      104
QR  208506121980       84
QR  208506011981       58
```

Gooseberry Creek Data

```
TT  GOOSEBERRY CREEK NEAR DICKIE, WY
TT  95 SQUARE MILE DRAINAGE
TT  ELEVATION 6592 FEET
TT  PECENKA
TT  STATION 62658 DISCONTINUED IN 1978
ID  2658  GOOSEBERRY CREEK
GS  2658            -.1
QR  265805001958    128
QR  265806001959     37
QR  265805001960     34
QR  265806001961    116
QR  265804001962    101
QR  265806001963    407
QR  265806001964    182
QR  265806001965    153
QR  265805001966     25
QR  265806001967    497
QR  265806001968    224
QR  265806001969     61
QR  265806001970    104
QR  265805001971    248
QR  265805001972     96
QR  265805001973    212
QR  265804001974    312
QR  265806001975    180
QR  265805001976     82
QR  265804001977     56
QR  265805001978    286
```

Inyan Kara Data

```
TT  INYAN KARA CREEK CROOK COUNTY
TT  STATION 64277 PEAK STREAMFLOW DATA
TT  PECENKA
TT  ELEVATION 4900 FT AREA 96.5 SQMI
TT  0 NONCONTRIBUTING
ID  4277  INYAN KARA CREEK
GS  4277              0
QR  427707011959   4660
QR  427705041960    420
QR  427700001961     72
QR  427706161962   1030
QR  427704021963    300
QR  427706221964    322
QR  427700001965    405
QR  427704111966    176
QR  427700001967     87
QR  427700001968     72
QR  427700001969    122
QR  427700001970    120
QR  427704191971    260
QR  427704191972    400
QR  427700001973     72
QR  427705221975     88
QR  427706141976    140
QR  427705161977     74
QR  427706301978    107
QR  427706171979    112
QR  427702181980     30
QR  427710211981    2.5
QR  427702221982     75
QR  427706181983     75
QR  427706091984    410
QR  427706251985    .05
```

APPENDIX C
TR55 Data Files

La Barge File

TR-55 CURVE NUMBER COMPUTATION VERSION 1.11

Project : LA BARGE CREEK User: JJP Date: 03-10-92

County : LINCOLN State: WY Checked: ____ Date: ________

Subtitle: SMALL STORAGE PROJECTS

Subarea : ONE

COVER DESCRIPTION		Hydrologic Soil Group A	B	C	D
		Sq miles (CN)			
FULLY DEVELOPED URBAN AREAS (Veg Estab.)					
Impervious Areas					
Paved parking lots, roofs, driveways		.14(98)	-	-	-
OTHER AGRICULTURAL LANDS					
Meadow -cont. grass (non grazed)	----	-	-	.1(71)	-
Brush - brush, weed, grass mix	good	-	-	.05(65)	-
Woods	fair	-	1.54(60)	-	-
ARID AND SEMIARID RANGELANDS					
Sagebrush (w/ grass understory)	fair	-	1.25(51)	-	-
Total Area (by Hydrologic Soil Group)		.14	2.79	.15	
		====	====	====	

SUBAREA: ONE TOTAL DRAINAGE AREA: 3.08 Sq miles WEIGHTED CURVE NUMBER:59

TR-55 CURVE NUMBER COMPUTATION VERSION 1.11

Project : LA BARGE CREEK User: JJP Date: 03-10-92

County : LINCOLN State: WY Checked: ____ Date: ________

Subtitle: SMALL STORAGE PROJECTS

Subarea : TWO

COVER DESCRIPTION		Hydrologic Soil Group A	B	C	D
		Sq miles (CN)			
FULLY DEVELOPED URBAN AREAS (Veg Estab.)					
Impervious Areas					
Paved parking lots, roofs, driveways		.25(98)	-	-	-
OTHER AGRICULTURAL LANDS					
Meadow -cont. grass (non grazed)	----	-	.25(58)	-	-
Brush - brush, weed, grass mix	fair	-	.5(56)	-	-
Woods	fair	-	1.11(60)	-	-
ARID AND SEMIARID RANGELANDS					
Sagebrush (w/ grass understory)	fair	-	2(51)	-	-
Total Area (by Hydrologic Soil Group)		.25	3.86		
		====	====		

SUBAREA: TWO TOTAL DRAINAGE AREA: 4.11 Sq miles WEIGHTED CURVE NUMBER:57

TR-55 CURVE NUMBER COMPUTATION VERSION 1.11

Project : LA BARGE CREEK User: JJP Date: 03-10-92

County : LINCOLN State: WY Checked: ____ Date: ________

Subtitle: SMALL STORAGE PROJECTS

Subarea : THREE

COVER DESCRIPTION		Hydrologic Soil Group A	B	C	D
		Sq miles (CN)			
FULLY DEVELOPED URBAN AREAS (Veg Estab.)					
Impervious Areas					
Paved parking lots, roofs, driveways		.15(98)	-	-	-
OTHER AGRICULTURAL LANDS					
Meadow -cont. grass (non grazed)	----	-	-	.1(71)	-
Brush - brush, weed, grass mix	fair	-	.15(56)	-	-
	good	-	.15(48)	-	-
Woods	good	-	.77(55)	-	-
ARID AND SEMIARID RANGELANDS					
Sagebrush (w/ grass understory)	fair	-	.6(51)	-	-
Total Area (by Hydrologic Soil Group)		.15	1.67	.1	
		====	====	====	

SUBAREA: THREE TOTAL DRAINAGE AREA: 1.92 Sq miles WEIGHTED CURVE NUMBER:57

TR-55 CURVE NUMBER COMPUTATION VERSION 1.11

Project : LA BARGE CREEK User: JJP Date: 03-10-92

County : LINCOLN State: WY Checked: ____ Date: ________

Subtitle: SMALL STORAGE PROJECTS

Subarea : FOUR

COVER DESCRIPTION		Hydrologic Soil Group A	B	C	D
		Sq miles (CN)			
FULLY DEVELOPED URBAN AREAS (Veg Estab.)					
Impervious Areas					
Paved parking lots, roofs, driveways		.1(98)	-	-	-
OTHER AGRICULTURAL LANDS					
Meadow -cont. grass (non grazed)	----	-	-	.15(71)	-
Brush - brush, weed, grass mix	fair	-	.25(56)	-	-
Woods	good	-	1.4(55)	-	-
ARID AND SEMIARID RANGELANDS					
Sagebrush (w/ grass understory)	good	-	.9(35)	-	-
Total Area (by Hydrologic Soil Group)		.1	2.55	.15	
		====	====	====	

SUBAREA: FOUR TOTAL DRAINAGE AREA: 2.8 Sq miles WEIGHTED CURVE NUMBER:51

TR-55 CURVE NUMBER COMPUTATION VERSION 1.11

Project : LA BARGE CREEK User: JJP Date: 03-10-92

County : LINCOLN State: WY Checked: ____ Date: ________

Subtitle: SMALL STORAGE PROJECTS

Subarea : FIVE

COVER DESCRIPTION		Hydrologic Soil Group A	B	C	D
		Sq miles (CN)			
FULLY DEVELOPED URBAN AREAS (Veg Estab.)					
Impervious Areas					
Paved parking lots, roofs, driveways		.05(98)	-	-	-
OTHER AGRICULTURAL LANDS					
Meadow -cont. grass (non grazed)	----	-	.05(58)	-	-
Brush - brush, weed, grass mix	fair	-	.1(56)	-	-
Woods	fair	-	.9(60)	-	-
ARID AND SEMIARID RANGELANDS					
Sagebrush (w/ grass understory)	fair	-	.35(51)	-	-
Total Area (by Hydrologic Soil Group)		.05	1.4		
		====	====		

SUBAREA: FIVE TOTAL DRAINAGE AREA: 1.45 Sq miles WEIGHTED CURVE NUMBER:59

TR-55 CURVE NUMBER COMPUTATION VERSION 1.11

Project : LA BARGE CREEK User: JJP Date: 03-10-92

County : LINCOLN State: WY Checked: ____ Date: ________

Subtitle: SMALL STORAGE PROJECTS

Subarea : SIX

COVER DESCRIPTION		Hydrologic Soil Group A	B	C	D
		Sq miles (CN)			
FULLY DEVELOPED URBAN AREAS (Veg Estab.)					
Impervious Areas					
Paved parking lots, roofs, driveways		.05(98)	-	-	-
OTHER AGRICULTURAL LANDS					
Meadow -cont. grass (non grazed)	----	-	-	.13(71)	-
Brush - brush, weed, grass mix	good	-	.1(48)	-	-
Woods	good	-	.9(55)	-	-
ARID AND SEMIARID RANGELANDS					
Sagebrush (w/ grass understory)	fair	-	.2(51)	-	-
Total Area (by Hydrologic Soil Group)		.05	1.2	.13	
		====	====	====	

SUBAREA: SIX TOTAL DRAINAGE AREA: 1.38 Sq miles WEIGHTED CURVE NUMBER:57

TR-55 CURVE NUMBER COMPUTATION VERSION 1.11

Project : LA BARGE CREEK User: JJP Date: 03-10-92
County : LINCOLN State: WY Checked: ____ Date: ________
Subtitle: SMALL STORAGE PROJECTS
Subarea : SEVEN

COVER DESCRIPTION		A	B	C	D
		Hydrologic Soil Group — Sq miles (CN)			
FULLY DEVELOPED URBAN AREAS (Veg Estab.)					
Impervious Areas					
Paved parking lots, roofs, driveways		.25(98)	-	-	-
OTHER AGRICULTURAL LANDS					
Meadow -cont. grass (non grazed)	----	-	-	.25(71)	-
Brush - brush, weed, grass mix	good	-	.26(48)	-	-
Woods	fair	-	2.25(60)	-	-
ARID AND SEMIARID RANGELANDS					
Sagebrush (w/ grass understory)	fair	-	.35(51)	-	-
Total Area (by Hydrologic Soil Group)		.25	2.86	.25	
		====	====	====	

SUBAREA: SEVEN TOTAL DRAINAGE AREA: 3.36 Sq miles WEIGHTED CURVE NUMBER:62

TR-55 CURVE NUMBER COMPUTATION VERSION 1.11

Project : LA BARGE CREEK User: JJP Date: 03-10-92

County : LINCOLN State: WY Checked: ____ Date: ________

Subtitle: SMALL STORAGE PROJECTS

Subarea : EIGHT

COVER DESCRIPTION		Hydrologic Soil Group A	B	C	D
		Sq miles (CN)			
OTHER AGRICULTURAL LANDS					
Meadow -cont. grass (non grazed)	----	-	-	.16(71)	-
Brush - brush, weed, grass mix	poor	-	.05(67)	-	-
Woods	fair	-	.2(60)	-	-
ARID AND SEMIARID RANGELANDS					
Sagebrush (w/ grass understory)	fair	-	.1(51)	-	-
Total Area (by Hydrologic Soil Group)			.35	.16	
			====	====	

SUBAREA: EIGHT TOTAL DRAINAGE AREA: .51 Sq miles WEIGHTED CURVE NUMBER:62

TR-55 CURVE NUMBER COMPUTATION VERSION 1.11

Project : LA BARGE CREEK User: JJP Date: 03-10-92

County : LINCOLN State: WY Checked: ____ Date: ________

Subtitle: SMALL STORAGE PROJECTS

Subarea : NINE

COVER DESCRIPTION		Hydrologic Soil Group A	B	C	D
			Sq miles (CN)		
OTHER AGRICULTURAL LANDS					
Meadow -cont. grass (non grazed)	----	-	-	.75(71)	-
Brush - brush, weed, grass mix	fair	-	.25(56)	-	-
Woods	fair	-	1.5(60)	-	-
ARID AND SEMIARID RANGELANDS					
Sagebrush (w/ grass understory)	fair	-	.54(51)	-	-
Total Area (by Hydrologic Soil Group)			2.29	.75	
			====	====	

SUBAREA: NINE TOTAL DRAINAGE AREA: 3.04 Sq miles WEIGHTED CURVE NUMBER:61

TR-55 CURVE NUMBER COMPUTATION VERSION 1.11

Project : LA BARGE CREEK User: JJP Date: 03-10-92

County : LINCOLN State: WY Checked: ____ Date: ________

Subtitle: SMALL STORAGE PROJECTS

Subarea : TEN

COVER DESCRIPTION		Hydrologic Soil Group A	B	C	D
			Sq miles (CN)		
OTHER AGRICULTURAL LANDS					
Meadow -cont. grass (non grazed)	----	-	-	1(71)	-
Brush - brush, weed, grass mix	good	-	1.2(48)	-	-
Woods	fair	-	3.62(60)	-	-
ARID AND SEMIARID RANGELANDS					
Sagebrush (w/ grass understory)	fair	-	1(51)	-	-
Total Area (by Hydrologic Soil Group)			5.82	1	
			====	====	

SUBAREA: TEN TOTAL DRAINAGE AREA: 6.82 Sq miles WEIGHTED CURVE NUMBER:58

TR-55 Tc and Tt THRU SUBAREA COMPUTATION VERSION 1.11

Project : LA BARGE CREEK User: JJP Date: 03-10-92

County : LINCOLN State: WY Checked: ____ Date: ________

Subtitle: SMALL STORAGE PROJECTS

------------------------------- Subarea #1 - ONE ------------------------------

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	1	300	.327	H					0.504
Shallow Concent'd		1000	.327	U					0.030
Open Channel		30571	.026			.0453	5		2.236
						Time of Concentration =			2.77*
Shallow Concent'd		1000	.327	U					0.030
Open Channel		30571	.026			.0453	5		2.236
								Travel Time =	2.27*

------------------------------- Subarea #2 - TWO ------------------------------

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	1	300	.23	H					0.580
Shallow Concent'd		1000	.23	U					0.036
Open Channel		20381	.011			.0263	5		1.324
						Time of Concentration =			1.94*
Shallow Concent'd		100	.23	U					0.004
Open Channel		20381	.011			.0263	5		1.324
								Travel Time =	1.33*

------------------------------ Subarea #3 - THREE -----------------------------

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	1	300	.2	H					0.614
Shallow Concent'd		1000	.2	u					0.038
Open Channel		16104	.045			.0261	3		0.765
						Time of Concentration =			1.42*
Shallow Concent'd		1000	.2	U					0.038
Open Channel		16104	.045			.0261	3		0.765
								Travel Time =	0.80*

* - Generated for use by TABULAR method

TR-55 Tc and Tt THRU SUBAREA COMPUTATION VERSION 1.11

Project : LA BARGE CREEK User: JJP Date: 03-10-92

County : LINCOLN State: WY Checked: ____ Date: ________

Subtitle: SMALL STORAGE PROJECTS

------------------------------ Subarea #4 - FOUR ------------------------------

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	1	300	.16	H					0.671
Shallow Concent'd		1000	.16	U					0.043
Open Channel		27984	.032		.0342		4		1.574
								Time of Concentration =	2.29*
									=====
Shallow Concent'd		1000	.16	U					0.043
Open Channel		27984	.032		.0342		4		1.574
								Travel Time =	1.62*
									=====

------------------------------ Subarea #5 - FIVE ------------------------------

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	1	300	.3	H					0.522
Shallow Concent'd		1000	.3	U					0.031
Open Channel		13094	.1		.0452		4		0.551
								Time of Concentration =	1.10*
									=====
Shallow Concent'd		1000	.3	U					0.031
Open Channel		13094	.1		.0452		4		0.551
								Travel Time =	0.58*
									=====

------------------------------ Subarea #6 - SIX ------------------------------

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	1	300	.17	H					0.655
Shallow Concent'd		1000	.17	U					0.042
Open Channel		16104	.098		.0351		3		0.698
								Time of Concentration =	1.39*
									=====
Shallow Concent'd		1000	.17	U					0.042
Open Channel		16104	.098		.0351		3		0.698
								Travel Time =	0.74*
									=====

------------------------------ Subarea #7 - SEVEN ------------------------------

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	1	300	.36	H					0.485
Shallow Concent'd		1000	.36	U					0.029
Open Channel		20328	.11		.0352		4		0.635

Time of Concentration = 1.15*
=====

Shallow Concent'd	1000	.36	U			0.029
Open Channel	20328	.11		.0352	4	0.635

Travel Time = 0.66*
=====

* - Generated for use by TABULAR method

TR-55 Tc and Tt THRU SUBAREA COMPUTATION VERSION 1.11

Project : LA BARGE CREEK User: JJP Date: 03-10-92

County : LINCOLN State: WY Checked: ____ Date: ________

Subtitle: SMALL STORAGE PROJECTS

------------------------------ Subarea #8 - EIGHT ------------------------------

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	1	300	.35	H					0.491
Shallow Concent'd		1000	.35	U					0.029
Open Channel		8606	.009		.0264		6		0.576
						Time of Concentration =			1.10*
Shallow Concent'd		1000	.35	U					0.029
Open Channel		8608	.009		.0264		6		0.576
							Travel Time =		0.61*

------------------------------ Subarea #9 - NINE ------------------------------

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	1	300	.32	H					0.509
Shallow Concent'd		1000	.32	U					0.030
Open Channel		13147	.021		.0265		7		0.550
						Time of Concentration =			1.09*
Shallow Concent'd		1000	.32	U					0.030
Open Channel		13147	.021		.0265		7		0.550
							Travel Time =		0.58*

------------------------------ Subarea #10 - TEN ------------------------------

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	1	300	.2	H					0.614
Shallow Concent'd		1000	.2	U					0.038
Open Channel		12672	.01		.02612		11		0.580
						Time of Concentration =			1.23*
Shallow Concent'd		1000	.2	U					0.038
Open Channel		12672	.01		.02612		11		0.580
							Travel Time =		0.62*

--- Sheet Flow Surface Codes ---

A Smooth Surface
B Fallow (No Res.)
C Cultivated < 20 % Res.
D Cultivated > 20 % Res.
E Grass-Range, Short
F Grass, Dense
G Grass, Burmuda
H Woods, Light
I Woods, Dense

--- Shallow Concentrated ---
--- Surface Codes ---

P Paved
U Unpaved

* - Generated for use by TABULAR method

TR-55 TABULAR DISCHARGE METHOD VERSION 1.11

Project : LA BARGE CREEK User: JJP Date: 03-10-92

County : LINCOLN State: WY Checked: ____ Date: ________

Subtitle: SMALL STORAGE PROJECTS

Total watershed area: 28.470 sq mi Rainfall type: II Frequency: 2 years

	ONE	TWO	THREE	FOUR	FIVE
Area(sq mi)	3.08*	4.11*	1.92*	2.80*	1.45*
Rainfall(in)	4.0	4.0	4.0	4.0	4.0
Curve number	59*	57*	57*	51*	59*
Runoff(in)	0.71	0.62	0.62	0.37	0.71
Tc (hrs)	2.77*	1.94*	1.42*	2.29*	1.10*
(Used)	0.10	2.00	1.25	0.20	1.25
TimeToOutlet	2.56*	1.23*	1.23*	1.20*	2.56*
(Used)	3.00	1.00	1.50	1.50	2.50
Ia/P	0.35	0.38	0.38	0.48	0.35

Time (hr)	Total Flow	Subarea Contribution to Total Flow (cfs) ONE	TWO	THREE	FOUR	FIVE
11.0	0	0	0	0	0	0
11.3	0	0	0	0	0	0
11.6	0	0	0	0	0	0
11.9	0	0	0	0	0	0
12.0	0	0	0	0	0	0
12.1	5	0	0	0	0	0
12.2	32	0	0	0	0	0
12.3	86	0	0	0	0	0
12.4	177	0	0	0	0	0
12.5	306	0	0	0	0	0
12.6	479	0	0	0	0	0
12.7	671	0	0	0	0	0
12.8	852	0	0	0	2	0
13.0	1204	0	5	0	22	0
13.2	1460	0	20	1	75	0
13.4	1676	0	51	9	140	0
13.6	1816	0	99	28	180	0
13.8	1942	2	165	64	186P	0
14.0	2072	20	234	112	166	2
14.3	2231	112	320	176	128	12
14.6	2300P	290	361P	203P	102	42
15.0	2251	481P	346	182	83	112
15.5	1900	404	280	133	68	175P
16.0	1493	248	224	100	61	160
16.5	1193	165	183	78	56	119
17.0	997	127	155	66	52	87
17.5	871	112	135	58	47	67
18.0	780	101	119	52	43	56
19.0	657	81	97	44	40	43
20.0	582	72	86	39	36	36
22.0	462	57	66	31	28	29
26.0	204	44	41	21	4	21

P - Peak Flow   * - value(s) provided from TR-55 system routines

TR-55 TABULAR DISCHARGE METHOD VERSION 1.11

Project : LA BARGE CREEK User: JJP Date: 03-10-92

County : LINCOLN State: WY Checked: ____ Date: ________

Subtitle: SMALL STORAGE PROJECTS

Continuation of subarea information

	Subareas				
	SIX	SEVEN	EIGHT	NINE	TEN
Area(sq mi)	1.38*	3.36*	0.51*	3.04*	6.82*
Rainfall(in)	4.0	4.0	4.0	4.0	4.0
Curve number	57*	62*	62*	61*	58*
Runoff(in)	0.62	0.86	0.86	0.81	0.66
Tc (hrs)	1.39*	1.15*	1.10*	1.09*	1.23*
(Used)	1.50	1.00	1.00	1.00	1.25
TimeToOutlet	2.56*	1.23*	0.62*	0.62*	0.00
(Used)	2.50	1.50	0.75	0.75	0.00
Ia/P	0.38	0.31	0.31	0.32	0.36

Time	Subarea Contribution to Total Flow (cfs)				
(hr)	SIX	SEVEN	EIGHT	NINE	TEN
11.0	0	0	0	0	0
11.3	0	0	0	0	0
11.6	0	0	0	0	0
11.9	0	0	0	0	0
12.0	0	0	0	0	0
12.1	0	0	0	0	5
12.2	0	0	0	0	32
12.3	0	0	0	0	86
12.4	0	0	0	0	177
12.5	0	0	0	2	304
12.6	0	0	2	10	467
12.7	0	0	5	27	639
12.8	0	0	11	59	780
13.0	0	0	33	178	966P
13.2	0	12	65	353	934
13.4	0	52	93	501	830
13.6	0	145	104P	566P	694
13.8	0	296	99	541	589
14.0	1	465	86	474	512
14.3	5	630P	65	361	422
14.6	21	604	49	274	354
15.0	62	456	36	203	290
15.5	115	296	27	153	249
16.0	128P	206	22	126	218
16.5	104	163	19	111	195
17.0	80	137	17	99	177
17.5	63	122	15	89	163
18.0	52	107	14	82	154
19.0	39	90	13	74	136
20.0	32	81	11	67	122
22.0	26	64	9	52	100
26.0	18	38	2	10	5

P - Peak Flow   * - value(s) provided from TR-55 system routines

TR-55 STORAGE VOLUME FOR DETENTION BASINS VERSION 1.11

Project : LA BARGE CREEK User: JJP Date: 03-10-92

County : LINCOLN State: WY Checked: ____ Date: ________

Subtitle: SMALL STORAGE PROJECTS

Drainage Area: 28.47 Sq miles Rainfall Frequency: 2 years

Rainfall-Type: II

Runoff: 6.7 inches

Peak Inflow: 2300 cfs

Detention Basin Storage Volume: 2000 acre-feet

Peak Outflow: 1707 cfs

6.7 inches

Pea

Inyan Kara File

TR-55 CURVE NUMBER COMPUTATION VERSION 1.11

Project : INYAN KARA User: JJP Date: 06-01-92

County : CROOK State: WY Checked: ____ Date: ________

Subtitle: SMALL STORAGE PROJECT

Subarea : ONE

COVER DESCRIPTION		Hydrologic Soil Group A	B	C	D
			Sq miles (CN)		
OTHER AGRICULTURAL LANDS					
Pasture, grassland or range	good	-	2(61)	-	-
Meadow -cont. grass (non grazed)	----	-	2(58)	-	-
Woods - grass combination	fair	-	5(65)	-	-
ARID AND SEMIARID RANGELANDS					
Pinyon - juniper	fair	-	7(58)	-	-
Sagebrush (w/ grass understory)	poor	-	2(67)	-	-
Total Area (by Hydrologic Soil Group)			18 ====		

SUBAREA: ONE TOTAL DRAINAGE AREA: 18 Sq miles WEIGHTED CURVE NUMBER:61

TR-55 CURVE NUMBER COMPUTATION VERSION 1.11

Project : INYAN KARA User: JJP Date: 06-01-92
County : CROOK State: WY Checked: ____ Date: ________
Subtitle: SMALL STORAGE PROJECT
Subarea : TWO

COVER DESCRIPTION		Hydrologic Soil Group A	B	C	D
		Sq miles (CN)			
OTHER AGRICULTURAL LANDS					
Pasture, grassland or range	fair	-	2(69)	-	-
Meadow -cont. grass (non grazed)	----	-	1(58)	-	-
Brush - brush, weed, grass mix	poor	-	2(67)	-	-
Woods - grass combination	poor	-	6(73)	-	-
ARID AND SEMIARID RANGELANDS					
Pinyon - juniper	poor	-	2(75)	-	-
Sagebrush (w/ grass understory)	poor	-	.64(67)	-	-
Total Area (by Hydrologic Soil Group)			13.6 ====		

SUBAREA: TWO TOTAL DRAINAGE AREA: 13.64 Sq miles WEIGHTED CURVE NUMBER:70

TR-55 CURVE NUMBER COMPUTATION VERSION 1.11

Project : INYAN KARA User: JJP Date: 06-01-92

County : CROOK State: WY Checked: ____ Date: ________

Subtitle: SMALL STORAGE PROJECT

Subarea : THREE

COVER DESCRIPTION		A	B	C	D
		Hydrologic Soil Group Sq miles (CN)			
OTHER AGRICULTURAL LANDS					
Pasture, grassland or range	fair	-	1(69)	-	-
Meadow -cont. grass (non grazed)	----	-	1(58)	-	-
Brush - brush, weed, grass mix	poor	-	1(67)	-	-
Woods - grass combination	poor	-	5(73)	-	-
ARID AND SEMIARID RANGELANDS					
Sagebrush (w/ grass understory)	fair	-	1.19(51)	-	-
Total Area (by Hydrologic Soil Group)			9.19 ====		

SUBAREA: THREE TOTAL DRAINAGE AREA: 9.19 Sq miles WEIGHTED CURVE NUMBER:67

TR-55 CURVE NUMBER COMPUTATION VERSION 1.11

Project : INYAN KARA User: JJP Date: 06-01-92

County : CROOK State: WY Checked: ____ Date: ________

Subtitle: SMALL STORAGE PROJECT

Subarea : FOUR

COVER DESCRIPTION		Hydrologic Soil Group A	B	C	D
		Sq miles (CN)			
OTHER AGRICULTURAL LANDS					
Pasture, grassland or range	good	-	-	5.3(74)	-
Meadow -cont. grass (non grazed)	----	-	3(58)	-	-
Brush - brush, weed, grass mix	poor	-	3(67)	-	-
Woods - grass combination	fair	-	2(65)	-	-
ARID AND SEMIARID RANGELANDS					
Pinyon - juniper	fair	-	4(58)	-	-
Sagebrush (w/ grass understory)	fair	-	1(51)	-	-
Total Area (by Hydrologic Soil Group)			13	5.3	
			====	====	

SUBAREA: FOUR TOTAL DRAINAGE AREA: 18.3 Sq miles WEIGHTED CURVE NUMBER:64

TR-55 CURVE NUMBER COMPUTATION VERSION 1.11

Project : INYAN KARA User: JJP Date: 06-01-92
County : CROOK State: WY Checked: ____ Date: ________
Subtitle: SMALL STORAGE PROJECT
Subarea : FIVE

COVER DESCRIPTION		Hydrologic Soil Group A	B	C	D
			Sq miles (CN)		
OTHER AGRICULTURAL LANDS					
Pasture, grassland or range	fair	-	.3(69)	-	-
Meadow -cont. grass (non grazed)	----	-	.1(58)	-	-
Brush - brush, weed, grass mix	fair	-	.4(56)	-	-
Total Area (by Hydrologic Soil Group)			.8 ====		

SUBAREA: FIVE TOTAL DRAINAGE AREA: .8 Sq miles WEIGHTED CURVE NUMBER:61

TR-55 CURVE NUMBER COMPUTATION VERSION 1.11

Project : INYAN KARA User: JJP Date: 06-01-92

County : CROOK State: WY Checked: ____ Date: ________

Subtitle: SMALL STORAGE PROJECT

Subarea : SIX

COVER DESCRIPTION		Hydrologic Soil Group A	B	C	D
			Sq miles (CN)		
OTHER AGRICULTURAL LANDS					
Pasture, grassland or range	fair	-	2(69)	-	-
Meadow -cont. grass (non grazed)	----	-	1(58)	-	-
Brush - brush, weed, grass mix	poor	-	1(67)	-	-
ARID AND SEMIARID RANGELANDS					
Pinyon - juniper	fair	-	2(58)	-	-
Sagebrush (w/ grass understory)	fair	-	.99(51)	-	-
Total Area (by Hydrologic Soil Group)			6.99 ====		

SUBAREA: SIX TOTAL DRAINAGE AREA: 6.99 Sq miles WEIGHTED CURVE NUMBER:61

TR-55 CURVE NUMBER COMPUTATION VERSION 1.11

Project : INYAN KARA User: JJP Date: 06-01-92

County : CROOK State: WY Checked: ____ Date: ________

Subtitle: SMALL STORAGE PROJECT

Subarea : SEVEN

COVER DESCRIPTION		Hydrologic Soil Group A	B	C	D
		Sq miles (CN)			
OTHER AGRICULTURAL LANDS					
Pasture, grassland or range	fair	-	.2(69)	-	-
Meadow -cont. grass (non grazed)	----	-	.1(58)	-	-
Brush - brush, weed, grass mix	fair	-	.1(56)	-	-
ARID AND SEMIARID RANGELANDS					
Pinyon - juniper	fair	-	.3(58)	-	-
Total Area (by Hydrologic Soil Group)			.7		
			====		

SUBAREA: SEVEN TOTAL DRAINAGE AREA: .7 Sq miles WEIGHTED CURVE NUMBER:61

APPENDIX D
Lag Times

La Barge Creek Lag Times

LAG TIME CALCULATION
LABARGE CREEK SYSTEM

CN I	CN II	CN III
51	70	85

SUB AREA	LENGTH FEET	STREAM SLOPE	GRID SLOPE	LATERAL SLOPE	AMC1 LAG	AMCII	AMCIII TIME
1	30571		0.34		18.26811	11.2183048	7.127035
2	KW				KW	KW	KW
3	13622		0.38		9.050785	5.55801712	3.531031
4	KW				KW	KW	KW
5	13094		0.32		9.555826	5.8681588	3.728066
6	KW				KW	KW	KW
7	16104		0.27		12.27582	7.53848553	4.789231
8	14020		0.28		10.78959	6.62580077	4.209399
9	KW				KW	KW	KW
10	20328		0.27		14.79038	9.08265499	5.770248
11	KW				KW	KW	KW
12	27984		0.34		17.02056	10.4521914	6.64032
13	KW				KW	KW	KW
14	8976		0.31		7.17746	4.40762265	2.800181
15	8035		0.21		7.981131	4.90115046	3.113721
16	KW				KW	KW	KW
17	12300		0.23		10.72125	6.58383819	4.18274
18	16526		0.23		13.57862	8.33852545	5.2975
19	16320		0.29		11.97188	7.35184094	4.670655
20	KW				KW	KW	KW
21	21225		0.36		13.25905	8.14227726	5.172822
22	20539		0.34		13.28952	8.16099206	5.184712
23	15892		0.26		12.37775	7.6010773	4.828996
24	21035		0.21		17.23573	10.5843293	6.724268
25	13050		0.26		10.57273	6.49263088	4.124795
26	23550		0.29		16.05385	9.85854239	6.263173
27	17890		0.24		14.16342	8.69764403	5.525649

KW IS ROUTE WITH KINEMATIC ADDITION

Gooseberry Creek Lag Times

LAG TIME CALCULATION
GOOSEBERRY CREEK SYSTEM

	CN I	CN II	CN III				
UP	45	65	82				
DOWN	60	78	90				
SUB AREA	**LENGTH FEET**	**STREAM SLOPE**	**GRID SLOPE**	**LATERAL SLOPE**	**AMC1 LAG**	**AMCII**	**AMCIII TIME**
1	38385	0.085	0.33	0.28	25.95564	15.5924006	9.604171
2	22862	0.017	0.25	0.12	19.70067	11.8348318	7.289689
3	23086	0.015	0.25	0.045	19.85493	11.9275066	7.346772
4	19536	0.01	0.25	0.066	17.37233	10.436124	6.428152
5	44352	0.0072	0.24	0.058	23.32899	14.3270411	9.458649
6	23760	0.0067	0.37	0.058	11.40374	7.00338254	4.623602

Inyan Kara Creek Lag Times

LAG TIME CALCULATION
INYAN KARA CREEK SYSTEM

CN I	CN II	CN III
50	69	84

SUB AREA	LENGTH FEET	STREAM SLOPE	GRID SLOPE	LATERAL SLOPE	AMC1 LAG	AMCII	AMCIII TIME
1	50635	0.025	0.14	0.044	43.7238	26.890329	17.21553
2	41184	0.0034	0.12	0.036	40.03257	24.6202058	15.76217
3	33264	0.012	0.12	0.023	33.74506	20.7533608	13.28657
4	43507	0.014	0.12	0.021	41.82905	25.7250466	16.4695
5	12672	0.004	0.094	0.066	17.61706	10.8345702	6.93643
6	15840	0.0082	0.11	0.037	19.46835	11.9731185	7.665343
7	6336	0.0039	0.11	0.061	9.353563	5.75248208	3.682812

APPENDIX E
Reservoir Stage Versus Storage

La Barge Reservoirs

LA BARGE STAGE VERSUS STORAGE IN FEET AND ACRE-FEET
Reservoir 1

0.045	AREA AT DAM HEIGHT	28.8	
	DAM LENGTH	500	FT.
	RESERVOIR LENGTH	3500	FT.
	XSECTION SLOPE	0.16	FT./FT.
	STREAM SLOPE	0.011429	FT./FT.
	AREA COEF	0.716873	

ELEVATION	AREA	DEL VOL	VOLUME	
8120	0	0	0	
8125	0.45	0.75	0.75	
8130	1.8	5.25	6	
8135	4.05	14.25	20.25	
8140	7.2	27.75	48	
8145	11.25	45.75	93.75	
8150	16.2	68.25	162	
8155	22.05	95.25	257.25	FULL
8160	28.8	126.75	384	TOP OF DAM
8165	36.45	162.75	546.75	OVERTOPPING BY 5 FEET
8170	45	203.25	750	OVERTOPPING BY 10 FEET

LA BARGE STAGE VERSUS STORAGE IN FEET AND ACRE-FEET
Reservoir 2

0.066	AREA AT DAM HEIGHT	42.24	
	DAM LENGTH	700	FT.
	RESERVOIR LENGTH	4000	FT.
	XSECTION SLOPE	0.114286	FT./FT.
	STREAM SLOPE	0.01	FT./FT.
	AREA COEF	0.657134	

ELEVATION	AREA	DEL VOL	VOLUME	
7960	0	0	0	
7965	0.66	1.1	1.1	
7970	2.64	7.7	8.8	
7975	5.94	20.9	29.7	
7980	10.56	40.7	70.4	
7985	16.5	67.1	137.5	
7990	23.76	100.1	237.6	
7995	32.34	139.7	377.3	FULL
8000	42.24	185.9	563.2	TOP OF DAM
8005	53.46	238.7	801.9	OVERTOPPING BY 5 FEET
8010	66	298.1	1100	OVERTOPPING BY 10 FEET

SOUTH LA BARGE STAGE VERSUS STORAGE IN FEET AND ACRE-FEET
Reservoir 3

0.035	AREA AT DAM HEIGHT	22.4	
	DAM LENGTH	400	FT.
	RESERVOIR LENGTH	2250	FT.
	XSECTION SLOPE	0.2	FT./FT.
	STREAM SLOPE	0.017778	FT./FT.
	AREA COEF	1.08416	

ELEVATION	AREA	DEL VOL	VOLUME	
8240	0	0	0	
8245	0.35	0.583333	0.583333	
8250	1.4	4.083333	4.666667	
8255	3.15	11.08333	15.75	
8260	5.6	21.58333	37.33333	
8265	8.75	35.58333	72.91667	
8270	12.6	53.08333	126	
8275	17.15	74.08333	200.0833	FULL
8280	22.4	98.58333	298.6667	TOP OF DAM
8285	28.35	126.5833	425.25	OVERTOPPING BY 5 FEET
8290	35	158.0833	583.3333	OVERTOPPING BY 10 FEET

Gooseberry Creek Reservoirs

GOOSEBERRY CREEK STAGE VERSUS STORAGE IN FEET AND ACRE-FEET
Reservoir 1

0.06	AREA AT DAM HEIGHT	38.4	
	DAM LENGTH	600	FT.
	RESERVOIR LENGTH	4224	FT.
	XSECTION SLOPE	0.133333	FT./FT.
	STREAM SLOPE	0.00947	FT./FT.
	AREA COEF	0.66	

ELEVATION	AREA	DEL VOL	VOLUME	
6280	0	0	0	
6285	0.6	1	1	
6290	2.4	7	8	
6295	5.4	19	27	
6300	9.6	37	64	
6305	15	61	125	
6310	21.6	91	216	
6315	29.4	127	343	FULL
6320	38.4	169	512	TOP OF DAM
6325	48.6	217	729	OVERTOPPING BY 5 FEET
6330	60	271	1000	OVERTOPPING BY 10 FEET

GOOSEBERRY CREEK STAGE VERSUS STORAGE IN FEET AND ACRE-FEET
Reservoir 2

0.1	AREA AT DAM HEIGHT	64	
	DAM LENGTH	1000	FT.
	RESERVOIR LENGTH	5491	FT.
	XSECTION SLOPE	0.08	FT./FT.
	STREAM SLOPE	0.007285	FT./FT.
	AREA COEF	0.507711	

ELEVATION	AREA	DEL VOL	VOLUME	
5960	0	0	0	
5965	1	1.666667	1.666667	
5970	4	11.66667	13.33333	
5975	9	31.66667	45	
5980	16	61.66667	106.6667	
5985	25	101.6667	208.3333	
5990	36	151.6667	360	
5995	49	211.6667	571.6667	FULL
6000	64	281.6667	853.3333	TOP OF DAM
6005	81	361.6667	1215	OVERTOPPING BY 5 FEET
6010	100	451.6667	1666.667	OVERTOPPING BY 10 FEET

GOOSEBERRY STAGE VERSUS STORAGE IN FEET AND ACRE-FEET
Reservoir 3

0.091	AREA AT DAM HEIGHT	58.24	
	DAM LENGTH	1000	FT.
	RESERVOIR LENGTH	7392	FT.
	XSECTION SLOPE	0.08	FT./FT.
	STREAM SLOPE	0.005411	FT./FT.
	AREA COEF	0.3432	

ELEVATION	AREA	DEL VOL	VOLUME	
5800	0	0	0	
5805	0.91	1.516667	1.516667	
5810	3.64	10.61667	12.13333	
5815	8.19	28.81667	40.95	
5820	14.56	56.11667	97.06667	
5825	22.75	92.51667	189.5833	
5830	32.76	138.0167	327.6	
5835	44.59	192.6167	520.2167	FULL
5840	58.24	256.3167	776.5333	TOP OF DAM
5845	73.71	329.1167	1105.65	OVERTOPPING BY 5 FEET
5850	91	411.0167	1516.667	OVERTOPPING BY 10 FEET

Inyan Kara Creek Reservoirs

INYAN KARA CREEK STAGE VERSUS STORAGE IN FEET AND ACRE-FEET
Reservoir 1

0.1	AREA AT DAM HEIGHT	64	
	DAM LENGTH	600	FT.
	RESERVOIR LENGTH	4963	FT.
	XSECTION SLOPE	0.133333	FT./FT.
	STREAM SLOPE	0.00806	FT./FT.
	AREA COEF	0.936208	

ELEVATION	AREA	DEL VOL	VOLUME	
5100	0	0	0	
5105	1	1.666667	1.666667	
5110	4	11.66667	13.33333	
5115	9	31.66667	45	
5120	16	61.66667	106.6667	
5125	25	101.6667	208.3333	
5130	36	151.6667	360	
5135	49	211.6667	571.6667	FULL
5140	64	281.6667	853.3333	TOP OF DAM
5145	81	361.6667	1215	OVERTOPPING BY 5 FEET
5150	100	451.6667	1666.667	OVERTOPPING BY 10 FEET

INYAN KARA STAGE VERSUS STORAGE IN FEET AND ACRE-FEET
Reservoir 2

0.11	AREA AT DAM HEIGHT	70.4	
	DAM LENGTH	400	FT.
	RESERVOIR LENGTH	7920	FT.
	XSECTION SLOPE	0.2	FT./FT.
	STREAM SLOPE	0.005051	FT./FT.
	AREA COEF	0.968	

ELEVATION	AREA	DEL VOL	VOLUME	
4960	0	0	0	
4965	1.1	1.833333	1.833333	
4970	4.4	12.83333	14.66667	
4975	9.9	34.83333	49.5	
4980	17.6	67.83333	117.3333	
4985	27.5	111.8333	229.1667	
4990	39.6	166.8333	396	
4995	53.9	232.8333	628.8333	FULL
5000	70.4	309.8333	938.6667	TOP OF DAM
5005	89.1	397.8333	1336.5	OVERTOPPING BY 5 FEET
5010	110	496.8333	1833.333	OVERTOPPING BY 10 FEET

INYAN KARA STAGE VERSUS STORAGE IN FEET AND ACRE-FEET
Reservoir 3

0.06	AREA AT DAM HEIGHT	38.4	
	DAM LENGTH	100	FT.
	RESERVOIR LENGTH	6336	FT.
	XSECTION SLOPE	0.8	FT./FT.
	STREAM SLOPE	0.006313	FT./FT.
	AREA COEF	2.64	

ELEVATION	AREA	DEL VOL	VOLUME	
4890	0	0	0	
4895	0.6	1	1	
4900	2.4	7	8	
4905	5.4	19	27	
4910	9.6	37	64	
4915	15	61	125	
4920	21.6	91	216	
4925	29.4	127	343	FULL
4930	38.4	169	512	TOP OF DAM
4935	48.6	217	729	OVERTOPPING BY 5 FEET
4940	60	271	1000	OVERTOPPING BY 10 FEET