Volume 1

OPERATION, MAINTENANCE AND SAFETY
MANUAL FOR THE MAGAT DAM

Magat River Integrated Irrigation System
Cauayan City, Isabela
November 2007
FOR : The Administrator
This Agency

THRU : The Deputy Administrator

FROM : The Acting Operations Manager
This System

SUBJECT : OPERATION, MAINTENANCE AND SAFETY MANUAL FOR THE MAGAT DAM

October 31, 2007

We have the honor to submit the updated Operation, Maintenance and Safety Manual for the Magat Dam for your approval and reference.

The Manual was prepared by a MARIIS Committee the membership of which was drawn from the different Divisions of MARIIS based on the 1985 Manual prepared by NIA and the 1992 Flood Operation Rule jointly prepared by NIA, NPC and PAG-ASA in coordination with the SN ABOITIZ Technical Staff.

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OPERATION, MAINTENANCE AND SAFETY MANUAL FOR THE MAGAT DAM

The members of the Technical Working Group (TWG) of both NIA-MARIIS and SN ABOITIZ inc. hereby propose the immediate adoption of this updated Manual in the operation and maintenance of the Magat High Dam and its appurtenant structures and facilities with the recommendation that whenever there are new policies, guidelines and/or technologies that need to be adopted, same must be incorporated into the Manual.

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PREFACE

The first Manual on Magat Operation and Dam Safety was published in 1982 a year before the 1983 official completion of the Magat River Multipurpose Project. This first edition did not include the requisite guidelines in operating the MARIIS and the Baligatan Diversion Dams. Due to this limitation, the Manual was revised in 1985 incorporating procedures on how to operate the two diversion dams. Also, significant operating experiences acquired by the Engineers operating the two dams were incorporated in the first revised version. To further improve the operation procedures for the Magat Dam especially during occurrences of floods, the Philippine Atmospheric Geophysical and Astronomical Administration (PAGASA) in cooperation with the National Irrigation Administration (NIA) and the National Power Corporation (NPC) came out with a Flood Operation Rule for the Magat Dam in April 1992. Ever since, the Magat Dam was operated based on these two Operation Manuals.

The past decade, however, saw the increasing need to update again the manual because of the apparent weather change affecting dam operation procedures, the plan of the PAGASA to improve its weather and flood forecasting system in the entire Cagayan River basin and the increased awareness and participation of the Local Government Units (LGUs), Non-Government Organizations (NGOs), private organizations, other stakeholders and the public on the impact of the Magat Dam in their lives and businesses especially during typhoons and floods. Also, the EPIRA law of 2001 mandates the unbundling of electricity - a major shift in the government policy on electricity. The law stipulates that major NPC generating assets shall be privatized to allow the government to generate much needed funds for its priority development projects. To carry this out, the Power Sectors Assets Liability Management (PSALM) was created to oversee the implementation of the law. As early as December 2006, PSALM was able to bid the asset of the NPC specifically the Magat Hydroelectric Power Plant (MHEPP) to the private sector. In December 13, 2006, NIA and SN ABOITIZ POWER Inc (SNAP) signed the Operation and Maintenance Agreement detailing the terms and conditions of the transfer. In April 2007, the ownership of the MHEPP was officially transferred to SNAP. While the change in ownership shall not necessarily need major changes in the overall operational procedures of the Magat dam and reservoir, there is a need to involve SNAP in the revision of the manual to ascertain that both parties (NIA and the SNAP) understand fully their respective obligations and roles in the operation of the Magat dam and reservoir.

And so, in its effort to address the above-cited needs, the NIA-MARIIS formed a Committee to review and update the present Dam Operation Manuals. With the full support of the NIA Central Office and PAGASA and the assistance and corroborations provided by the SNAP, the Committee came out with this second revision of the Dam Operation, Maintenance and Safety Manual. The organization of contents has been improved to give more emphasis on Reservoir Operation. The Emergency Action Plan was maintained immediately following this Preface to make it readily accessible to follow in case of emergency operation.

Some of the organizational titles formerly used in the first edition were likewise changed to reflect the current organizational/position titles being used.
The Committee members who came from the different Divisions of MARIIS worked hard making use of their extra time inside and outside of the office to come up with this revised manual.

The Committee is thankful to the management of NIA Central Office for their full support, recommendations and encouragement during the preparation of the manual.

Special acknowledgement is due the SNAP officials – CEO Emmanuel V. Rubio and Chief Technology Officer Stig Olav Aksdal – for their critical inputs. The Data Encoders of MARIIS District IV and DRD also spent long encoding and printing hours to complete this Manual. They likewise deserve special commendation.

The MARIIS Committee in the Preparation of the Dam Operations Manual.

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ACKNOWLEDGEMENT

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MAGAT CONTINGENCY PLAN

I. GENERAL

The land and water resources of the Philippines make possible a hydrosystem suitable for irrigation and power generation. Along this line, several man-made dams were built in different areas of the archipelago providing tremendous potential for irrigation development and power generation.

One of these dams is the Magat Dam in Ramon, Isabela, which by world standards is a major structure.

The Magat Dam has a maximum height of 114 meters above the riverbed and comprises of 4,160 meter long earth and rockfill embankment with concrete headworks. The concrete headworks are located at the North bank of the Magat river. The Ogee-shaped spillway structure located at the headworks has seven large radial gates which will, in times of flood, release floodwaters down to the outlet channel. There are two orifice gates located at a lower elevation to assist in passing large flood flows through the spillway in times of extreme emergency and to release irrigation water when reservoir elevation is below elevation 174 m.

The embankment dam is provided with various instrument/devices to monitor behavior of the embankments.

In strategic points downstream of the Magat Dam are 15 sirens, an integral part of the entire Magat Early Flood Forecasting and Warning System, intended to warn residents within the area of impending water release from the dam during times of floods.

While the Magat Dam offers opportunities for economic growth in the region, there exist the remote possibility that it can cause flooding downstream in cases of continuous heavy rains in its watershed area if the releases from its spillway shall not be strictly regulated.

II. OBJECTIVE

The main objective of this plan is to establish an effective system of disaster preparedness and develop detailed procedures to be followed in order to prevent or mitigate the possible loss of human lives and damage to crops and properties in areas downstream of the Magat Dam in cases of emergency situations.

III. CONCEPT

While the more technical aspect of ensuring timely and proper releases of dam water during an emergency or unusual occurrence is now entrusted to the PAGASA by virtue of a Presidential directive issued last December 12, 2006, the MARIIS
Operations Manager (MARIIS OM) and his Staff shall be responsible in carrying out the plan as outlined in Chapter IV of this Operation & Maintenance Manual and in the Flood Operation Rule for Magat Dam prepared by PAGASA. Likewise, Agencies identified in this Plan would be tapped to form a Committee to maximize civic action thereby minimizing the ill-effects of the contingency. Thus, disaster preparedness becomes a joint responsibility of PAGASA, NIA and every political and administrative subdivision in the locality as well as private organizations and the general public in the flood-prone areas.

IV. ACTION PLAN FOR EMERGENCY RELEASE OF WATER

A. PAGASA shall undertake the forecasting of rainfall in the watershed and the expected volume and rate of flood flows. It shall likewise promptly advise the MARIIS OM and the Manager of the DRD (DRD Manager) if a decision to pre-release was arrived at indicating therein the time of pre-release, the volume of water to be released and the required drawdown elevation. In case of spilling, the sequence of spillway operation as outlined in Sec. 4.2.2, Chapter IV of this Manual shall be strictly followed.

B. Upon receipt of the Notice of pre-release, The DRD Manager shall inform immediately the Office of the Operations Manager of the decision to pre-release, the volume to be released and the time of pre-release. Likewise, he shall inform the Governors of Nueva Vizcaya, Isabela and Cagayan, the Mayors in the target area and the Station Managers or their on-duty official of the broadcast media at least three hours before the actual release of water from the spillway. A system shall be devised using all available means of communications to identify the sending end and receiving end parties to avoid false information relayed or received by either side. A log book shall likewise be kept at the office of the Instrumentation and Flood Forecasting/Warning Section of the Dam and Reservoir Division (DRD) to record the date and time the messages were sent/received.

C. The Office of the Governors shall likewise disseminate the information on the pre-release, the volume to be released and the time of pre-release to all concerned Mayors to ensure that the information shall be received. He shall likewise put into action all Disaster Coordinating Councils in each municipality and barangays for disaster preparedness.

D. The PAGASA shall inform the OCD and the DPWH about the pre-release.

E. The DRD Manager shall issue hourly bulletins to all radio stations by any fastest means available for immediate broadcast.

F. The Instrumentation Section of the DRD shall activate the downstream flood warning sirens promptly corresponding with the urgency of the situation.
V. ORGANIZATION

One of the objectives of this Magat Contingency Plan is to organize an Inter-Agency Committee to execute necessary warning as well as support/assistance to all affected residents. The extent of the inter-agency coordination/participation is outlined below:
Shown below are the coordination process and the extent of communication networks that shall be always on standby and ready to respond in cases of emergencies:

**COMMUNICATIONS NETWORK FOR FLOOD WARNING OPERATION**

VI. COORDINATING INSTRUCTION

All agencies involved shall develop and execute their respective action plans in support of this Contingency Plan.

The Office of Civil Defense shall coordinate the activities and functions of the different agencies involved in the implementation of this plan.
VII. ADMINISTRATION AND LOGISTICS

All agencies involved shall provide their own logistics and financial support for short term as well as long term operations. Control and direction of activities in accordance with this plan shall be handled by respective Agencies concerned through the office of the Civil Defense.

NIA-MARIIS is mandated to operate, maintain and administer the Magat Dam. In addition, it has to comply fully and promptly with all its obligations stipulated in the Operation and Maintenance Agreement it entered into with SNAP regarding the efficient utilization of the water stored in the Magat reservoir for irrigation and power generation. These added obligations of NIA-MARIIS are detailed in Schedule B of the NIA-SN ABOITIZ POWER Memorandum of Agreement.

It is therefore important that adequate logistic support be provided to MARIIS to ensure that its primary role as the Operator of the Magat Dam Complex shall not be sacrificed or prejudiced.

Mobility of personnel is one critical component of a successful operation and maintenance. Lack or absence of it shall mean big setbacks especially in time of emergencies. Safe dam operation means leaving no room for inadequacies because of the high stakes involve – possible loss of lives, loss or damage to properties and crops.

At present, most MARIIS service vehicles are no longer dependable having outlived their economic lives. Field personnel oftentimes complain that their performance is greatly hampered because of lack of and inefficient service vehicles. Worse, the cost of maintaining these vehicles keeps piling through the years.

MARIIS is in dire need for new service vehicles. This need was acknowledged even during the initial discussions on the terms and conditions of the NIA-SN ABOITIZ POWER Agreement and later by the Technical Working Groups (TWGs) of both MARIIS and SNAP and strongly recommended for the acquisition of the needed vehicles. NIA must find ways to address this lack of vehicle problem immediately to provide the environment for a continuous and efficient O & M of the Magat Dam Complex and the other MARIIS Offices.

A. Service Vehicles

1. SNAP will provide the NIA and its duly authorized representatives, the possession, usage and control of service vehicles to enable NIA to perform the services prescribed in Schedule B of the Operations and Maintenance Agreement between NIA and SNAP. The details of the service vehicles to be provided by SNAP to NIA are described in detail in Annex “A”.

2. The total cost of the service vehicles described in Annex “A” shall be deducted from the NIA’s Service Fees until SNAP has been fully reimbursed for such total
cost. The amount to be deducted and the frequency of the deduction shall be provided in a schedule attached hereto as Annex “B”. When SNAP has been fully reimbursed for the total cost of the service vehicles, both SNAP and NIA shall execute the necessary deed of absolute sale to effect the transfer of the service vehicles in the name of NIA. Prior to the execution of such deed of absolute sale, SNAP remains the absolute owner of the service vehicles and any improvements which may have been introduced by NIA to the service vehicles.

B. Term

The usage of the service vehicles by NIA is co-terminous with the Term of the O & M Agreement. Unless otherwise agreed upon by the parties in writing, upon termination or pre-termination of the O & M Agreement and provided that SNAP has not yet been fully reimbursed for the total cost of the service vehicles, such service vehicles shall be immediately returned to SNAP and the portion of the Service Fees deducted by SNAP for the service vehicles shall be returned to NIA.

C. Use and Maintenance of the Service Vehicles

1. NIA shall have possession and control of the service vehicles and shall be solely responsible for the operation, maintenance, repair, and preservation of the service vehicles. It is furthermore agreed upon that NIA shall bear the obligations and liabilities, as well as any and all costs, in relation to the operation, maintenance, repair, and preservation of the service vehicles, at its own account and expense and at no expense whatsoever to SNAP. It is further understood that operation and maintenance cost includes, but is not limited to, the registration of the service vehicles and expenses for gasoline, repair and regular maintenance check-up.

2. NIA shall exercise extraordinary diligence in the operation, maintenance, repair, and preservation of the service vehicles, and shall ensure that the service vehicles are legally and properly operated and maintained. NIA shall at all times secure and maintain a comprehensive insurance policy based on the appraisal value of the service vehicles to be disclosed by SNAP against any damage, loss or liability of the service vehicles or such damage or accidents caused to others by the use of said service vehicles. In such policies, the insured and/or the beneficiary therein should be SNAP.

3. NIA shall not assign, mortgage or create any security interest over the service vehicles without the prior written consent and approval of SNAP.

4. NIA completely and absolutely releases and relieves SNAP of any and all responsibility, liability, obligation, expense or such other costs, including legal costs and fees, related to the service vehicles, regardless of the nature, extent or scope thereof. NIA further undertakes and agrees to indemnify SNAP free and harmless, from and against any and all liabilities, costs and expense (including reasonable attorneys’ fees and any and all judgments, fines and any other amounts
imposed or paid in settlement) in connection with any claim, action, suit, or proceeding, including those threatened or pending, whether civil, criminal administrative, or investigative, arising from any claim, action, suit or proceeding against NIA that will necessarily or eventually involve or affect SNAP on the use, possession, control, operation, maintenance, repair, and preservation of the service vehicles. NIA likewise gives SNAP the right and authority to automatically withhold or set off any such amount due or owing SNAP from such amount due or owed to NIA under the terms and conditions set out in the O & M Agreement.
CHAPTER I

INTRODUCTION

1.1 GENERAL

Presidential Decree 693 signed on May 7, 1975 by the late President Ferdinand E. Marcos authorized the construction of the Magat Dam and its appurtenant structures. The implementation of the Magat River Multipurpose Project (MRMP) was based on the preliminary study conducted in 1973 by the National Irrigation Administration (NIA) with the assistance of the United State Agency for International Development (USAID).

Subsequent detailed and extensive damsite investigation and engineering studies confirmed the feasibility of what is now known as NIA’s most daring infrastructure project and one of Asia’s biggest dams today.

The Magat Dam which was completed on October 27, 1982 is located about six (6) kilometers upstream of the MARIS Diversion Dam and about 360 kilometers north of Manila.

The Philippine Government and the World Bank which extended a $150 million loan for the foreign exchange requirement jointly financed the project. In addition, a $9 million loan from Bahrain was obtained for the purchase of other equipment for the diversion tunnels, soils laboratory and model testing. The total cost of the project is P3.4 billion.

The project was implemented in two stages. The first stage involved the rehabilitation and upgrading of the two (2) existing irrigation systems namely: the Siflu River Irrigation System (SIFRIS) and the Magat River Irrigation System (MARIS) and the development of extension and new areas. The second stage was the construction of a storage dam across the Magat River. The implementation of MRMP lasted for thirteen years (from January 1974 to December 1986) under the management and supervision of the National Irrigation Administration (NIA).

The Magat River Integrated Irrigation System (MARIIS) is the forerunner of MRMP. The MARIIS integrates the operation, management, supervision and maintenance of the Magat Dam Complex including the reservoir and resettlement areas, the Baligatan Hydro Electric Power Plant, irrigation and drainage facilities and roads within the MARIS and SIFRIS, Baligatan Outlet Works, Pumping Stations and Transmission Line.

Construction contracts were awarded as follows:

Diversion Tunnel - Hydro Resources Contractors Corporation-January 1978

Main Civil Works - Hydro Resources Contractors Corporation-August 1978

Tunnel 2 was completed in May 1980 and the river was diverted in the same month. Tunnel 1 was closed on December 12, 1981 and Tunnel 2 was closed on March 7, 1982 to allow the initial (partial) filling of the reservoir. Construction of the Magat Dam Complex was completed by late 1982, except for the Baligatan Power Plant which was completed in March 1987.

The Magat Hydroelectric Plant was constructed by the National Power Corporation and the first unit was commissioned in September 1983.

The Baligatan Hydroelectric Power Plant was constructed by National Irrigation Administration and the plant was commissioned in 1987.

1.2 PURPOSE, FORMAT AND SCOPE OF MANUAL

This Volume of the Manual is just one of the key operating instructions for the Magat Dam Complex. It has been prepared to provide the information necessary to enable the Magat Dam and its appurtenant facilities to be operated and maintained safely throughout their full life. **THE SAFETY OF THE DAM MUST ALWAYS HAVE TOP PRIORITY.**

Procedures are included to enable gates and equipment to be operated properly, to define when gates are to be operated and to form the framework for a comprehensive maintenance program.

The inspection and maintenance of the concrete and rockfill structure are covered in considerable detail. The importance of proper inspection and maintenance cannot be over emphasized. Constant inspection and early maintenance form the best protection against possible failure of the structures.

The Manual comprises thirteen volumes. The first four volumes contain general operation and maintenance information, instructions, and drawings for the dams appurtenant structures, instrumentation and equipment of the Magat Dam Complex. The titles and brief description of contents of these volumes are:

- **Volume 1** - General Operations and Maintenance Manual Contains operation and Maintenance instructions for dam, structures and equipment
- **Volume 2** - Drawings and Appendices Contains drawing and appendices pertinent to Volume 1
- **Volume 3** - Instrumentation Manual Contains detailed operations and maintenance instructions for instrumentation equipment
- **Volume 4** - Instrumentation Manufacturers Manuals and Catalogs
Volumes 5 through 13 contain detailed operating and maintenance instructions, information, catalog lists and drawings for particular electrical and mechanical equipment. Each has been prepared by the supplier of the particular equipment covered. The lists of recommended spare parts which should be carried in stock at Magat damsite are included in these volumes. The required systems for maintenance painting are also included.

Volumes for equipment in the Magat Hydro Electric Power Plant and the Baligatan Hydro Electric Power Plant are not included in this Manual. The operations and maintenance manual for the Main Power Plant was prepared by, and is in the possession of the National Power Corporation. The operations and maintenance manual for the Baligatan Hydro Electric Power Plant’s equipment was prepared by the China National Machineries and Equipment Import and Export Corporation (CMEC).

The titles and brief description of contents of these volumes are:

Volume 5 - O & M Instructions, Ogee Spillway Gates and Stop Logs
Volume 6 - O & M Instructions, Power Intake Closure Gate Bulkhead, and Trash racks
Volume 7 - O & M Instructions, Travelling Gantry Crane
Volume 8 - O & M Instructions, Orifice Spillway Gates and Stop Logs
Volume 9 - O & M Instructions, Spherical Valve
Volume 10 - O & M Instructions, Baligatan Outlet Control and Guard Gate
Volume 11 - O & M Instructions, Incoming Panel Dry Type Transformer and No-Fuse Breakers Instruction Manual
Volume 12 - O & M Instructions, Baligatan Diversion Dam Gates
Volume 13 - O & M Instructions, Emergency Power Generator Unit
### 1.3 IMPORTANT OPERATING PRECAUTIONS

<table>
<thead>
<tr>
<th>PARTICULARS</th>
<th>Dos</th>
<th>DO NOTs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Reservoir</td>
<td>Do open the spillway gates when reservoir rises above elevation 193.00 m and the power plants are operating at full capacity or when there is decision to pre-release.</td>
<td>Do not store flood waters above elevation 193 m except when the flood flows can not be fully discharged even with all the spillway gates open.</td>
</tr>
<tr>
<td>2. Ogee spillway gates</td>
<td><strong>DO continue to open gates</strong> while the reservoir is still rising above elevation 193.00 m following the steps in Table 4.1</td>
<td><strong>Gate opening</strong>&lt;br&gt;DO NOT open gates any further if reservoir elevation is steady or falling.</td>
</tr>
<tr>
<td>3. Orifice Spillway gates</td>
<td><strong>DO ensure that the sirens are sounded</strong> at each step and check that they are being heard in the target area.</td>
<td><strong>Gate Closing</strong>&lt;br&gt;DO NOT continue to close gates if reservoir is steady or rising</td>
</tr>
<tr>
<td>4. Ogee and Orifice stoplogs</td>
<td><strong>DO close gates quickly enough to prevent the reservoir from falling below elevation 193.00 m. Do follow the steps in Table 4.1 in reverse sequence.</strong>&lt;br&gt;<strong>DO operate Gate 7 to clear flood debris.</strong>&lt;br&gt;<strong>DO install and remove over 8,540m3/s.</strong>&lt;br&gt;<strong>DO follow Table 4.1</strong>&lt;br&gt;<strong>DO install and remove equal water pressure on each side.</strong></td>
<td><strong>DO NOT attempt to lower gate if there are any obstruction beneath.</strong>&lt;br&gt;<strong>DO NOT use grease containing molybdenum disulfide or other solid additives.</strong>&lt;br&gt;<strong>DO NOT attempt to handle more than 1 section at a time.</strong></td>
</tr>
<tr>
<td>Area</td>
<td>Instructions</td>
<td></td>
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<tr>
<td>--------------------</td>
<td>------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Power intake</td>
<td>DO close the closure gate and bulkhead gate before removing trash racks.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bulkhead gate is closed so that debris does not reach closure gate. DO</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Install and remove the bulkhead with equal water pressure on each side. DO</td>
<td></td>
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<tr>
<td></td>
<td>check for correct rotation of hoist pump when re-assembling after</td>
<td></td>
</tr>
<tr>
<td></td>
<td>maintenance.</td>
<td></td>
</tr>
<tr>
<td>Headworks Gantry</td>
<td>DO position the hook directly over the loads. DO</td>
<td></td>
</tr>
<tr>
<td></td>
<td>replace wire ropes when kinked, corroded deformed or when diameter is</td>
<td></td>
</tr>
<tr>
<td></td>
<td>reduced by 7% or more.</td>
<td></td>
</tr>
<tr>
<td>Baligatan Outlet</td>
<td>DO check that locking device is unlocked before lowering guard gates. DO</td>
<td></td>
</tr>
<tr>
<td>Works</td>
<td>check piping systems regularly for leaks.</td>
<td></td>
</tr>
<tr>
<td>MARIS Dam</td>
<td>DO remove stop logs by the time Magat reservoir is re-filling and reaches</td>
<td></td>
</tr>
<tr>
<td></td>
<td>elevation 175.00 meters.</td>
<td></td>
</tr>
</tbody>
</table>

**DISTRIBUTION AND CUSTODY OF THE MANUAL, REVISION AND AMENDMENTS**

The reproduction, distribution and custody records of this Operation and Maintenance and Dam Safety Manual and all supporting documents thereto are the joint responsibility of the MARIS Technical Working Group (TWG) and the Dam Safety Officer, National Irrigation Administration Central Office, Quezon City. The official distribution list of this Manual, revisions, addenda and amendments thereto is as follows:
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<th>Particulars</th>
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<tr>
<td>Dam &amp; Reservoir Division, MARIIS (DRD-MARIIS) Ramon, Isabela</td>
<td>6</td>
<td>DRD Manager (1)</td>
</tr>
<tr>
<td>HEAD OFFICE MARIIS Cauayan City Isabela</td>
<td>6</td>
<td>Head, Civil Works Section (1)</td>
</tr>
<tr>
<td>NIA-Central Office, Quezon City</td>
<td>6</td>
<td>Head, Instrumentation Section (1)</td>
</tr>
<tr>
<td></td>
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<td>Head, Electrical-Mechanical Section (1)</td>
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<td>Head, Watershed Management Section (1)</td>
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<td>Head, Administrative Section (1)</td>
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<tr>
<td></td>
<td></td>
<td>Operations Manager MARIIS(1)</td>
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<tr>
<td></td>
<td></td>
<td>Manager, EOD (1)</td>
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<tr>
<td></td>
<td></td>
<td>District Offices (4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Central Library (1)</td>
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<tr>
<td></td>
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<td>AA for SOEM (1)</td>
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<tr>
<td></td>
<td></td>
<td>Systems Management Dept. (1)</td>
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<tr>
<td></td>
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<td>Design &amp; Specs. Department (1)</td>
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<tr>
<td></td>
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<td>Construction Management Department (1)</td>
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<tr>
<td></td>
<td></td>
<td>Equipment Management Dept (1)</td>
</tr>
<tr>
<td>RDCC Region 2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>PAGASA</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>SNABOITIZ</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>
All copies of this manual are to be kept current. For this reason, the number of copies prepared has been limited to copies required for official distribution. All copies of the Manual have been numbered and dated for additional means of control. In case of any revision, a copy of the revision shall be filed in front of the revised volume of this manual.

**SUPPORTING DOCUMENTS**

Construction of the structure and installation of equipment in the Magat Dam Complex required and produced many documents which support the instructions and procedures contained in this Manual. It may be necessary, from time to time, to refer to these documents for additional data or background information to support decisions or actions relative to operation and maintenance. Some of the more important documents are listed below, along with their archival locations, for convenient reference to possible sources of supporting information and data.

**MAGAT RIVER PROJECT FEASIBILITY REPORT 1973** - PDD Central Office

**PROJECT DESIGN REPORT (PART A), September 1976** - DSD Central Office

**PROJECT DESIGN REPORT (PART B)** - DSD Central Office

**HYDRAULIC MODEL INVESTIGATING (VOLUMES I through X)**

**NATIONAL HYDRAULIC RESEARCH CENTER 1980** - DSD Central Office

**CONTRACT DOCUMENTS** - CMD Central Office

**CONSTRUCTION MONTHLY PROGRESS REPORTS** - CMD Central Office

**GOOD FOR CONSTRUCTION DRAWING (ORIGINALS)** - MAGAT DAM SITE OFFICE

**OPERATING AGREEMENT BETWEEN NIA & NPC** - CMD, Central Office

This list needs to be updated from time to time in case there are results of new studies such as Flood Forecasting and Warning System for Dam Operation.

**REFERENCE MATERIALS**

Following is a list of reference materials which may be useful in the operation and maintenance of the Magat Dam Complex.

**NATIONAL IRRIGATION ADMINISTRATION, QUEZON CITY, PHILIPPINES NIA Dam Safety Program Manual of Guidelines and Procedures.**
MAGAT DAM COMPLEX STATISTICAL SUMMARY

PROJECT PURPOSE

Firmed Service Area 84,795 ha.

Power 360 MW
(w/provision for additional 180 MW)

HYDROLOGY

Drainage Area 4,143 sq. km.

Runoff @ Damsite

Annual Average 6,698 mcm

Peak recorded Discharge 29,480 cms
(October 1971)

Design Flood

Peak Inflow 34,453 cms

10-day Volume 8,420 mcm
PROJECT FEATURES

Reservoir Area @ FSL, Crest Elevation, MSL  
45 km² 200 m

Maximum Water Surface (MWS-Flood), MSL  
197 m

Full Supply Level, MSL  
193 m

Minimum Supply Level, (MSL)  
160 m

STORAGE CAPACITY

Total at FSL (193 m, w/o sedimentation)  
1.25 BCM

Total at MSL (160 m, w/o sedimentation)  
317 MCM

Live Storage (193 m – 160 m)

Without Sedimentation  
933 MCM

After 50 years Operation  
832 MCM

Surface Area

At FSL (193 m),  
45 km²

At MSL (160 m), km²  
15 km²

DAM (Total Crest Lengths – Embankment Dams and Dikes including Headworks Structure)  
4,160 m

NORTH EMBANKMENT DAM

Type  Zoned Earth-Rockfill with Inclined Core

Crest Elevation (above mean sea level)  
200.50 m

Maximum Height  
35 m

Crest Width  
12 m

Crest Length  
300 m

Upstream Slope  
2.4:1

Downstream  
1.8:1
### MAIN EMBANKMENT DAM

<table>
<thead>
<tr>
<th>Type</th>
<th>Zoned Earth-Rockfill with Inclined Core</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crest Elevation (above mean sea level)</td>
<td>200.50 m</td>
</tr>
<tr>
<td>Maximum Height</td>
<td>114.00 m</td>
</tr>
<tr>
<td>Crest Width</td>
<td>12 m</td>
</tr>
<tr>
<td>Crest Length</td>
<td>1,000 m</td>
</tr>
<tr>
<td>Maximum Base Width</td>
<td>500 m</td>
</tr>
<tr>
<td>Upstream Slope</td>
<td>2.4:1</td>
</tr>
<tr>
<td>Downstream</td>
<td>1.8:1</td>
</tr>
<tr>
<td>Embankment Volume</td>
<td>18 m$^3$</td>
</tr>
</tbody>
</table>

### NORTH BALIGATAN DIKE

<table>
<thead>
<tr>
<th>Type</th>
<th>Zoned Earth-Rockfill with Vertical Core and Stabilizing Bern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crest Elevation (above mean sea level)</td>
<td>200.50 m</td>
</tr>
<tr>
<td>Maximum Height</td>
<td>30.00 m</td>
</tr>
<tr>
<td>Crest Width</td>
<td>12.00 m</td>
</tr>
<tr>
<td>Crest Length</td>
<td>1,500 m</td>
</tr>
<tr>
<td>Upstream Slope</td>
<td>2.4:1</td>
</tr>
<tr>
<td>Downstream</td>
<td>2.25:1</td>
</tr>
</tbody>
</table>

### BALIGATAN EMBANKMENT DAM

<table>
<thead>
<tr>
<th>Type</th>
<th>Zoned Earth-Rockfill with Inclined Core and Stabilizing Bern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crest Elevation (above mean sea level)</td>
<td>200.50 m</td>
</tr>
<tr>
<td>Maximum Height</td>
<td>50.00 m</td>
</tr>
<tr>
<td>Crest Width</td>
<td>12.00 m</td>
</tr>
<tr>
<td>Property</td>
<td>Value</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>-----------</td>
</tr>
<tr>
<td>Crest Length</td>
<td>700.00 m</td>
</tr>
<tr>
<td>Upstream Slope</td>
<td>2.4:1</td>
</tr>
<tr>
<td>Downstream Slope</td>
<td>1.8:1</td>
</tr>
</tbody>
</table>

**SOUTH BALIGATAN DIKE**

- **Type**: Zoned Earth-Rockfill with Inclined Core and Stabilizing Bern
- **Crest Elevation (above mean sea level)**: 200.50 m
- **Maximum Height**: 30.00 m
- **Crest Width**: 12.00 m
- **Crest Length**: 350.00 m
- **Upstream Slope**: 2.4:1
- **Downstream Slope**: 1.8:1

**HEADWORKS STRUCTURE (SPILLWAY AND POWER INTAKE)**

- **Spillway Headworks**
- **Type**: Ogee and Orifice
- **Type of Gates (Ogee and Orifice)**: Radial
- **Number and Dimension of Ogee Crest Gates**: 7-16.5 m x 20 m
- **Number and Dimension of Orifice Gates**: 2-6 m x 12.5 m
- **Ogee Crest Elevation**: 174.00 m
- **Orifice Invert Elevation**: 147.00 m
- **Maximum Discharge Capacity**: 30,600 m³/s

**POWER INTAKE HEADWORKS**

- **Number of Intakes**: 6 (four operable, 2 for future use)
- **Type**: Orifice with Central Pier
- **Type of Gates**: Fixed Wheel Gate
Number and Dimension of Gates
6-5 m x 5.527 m
Orifice Invert Elevation 147.50 m

**HEADWORKS**

Crest Elevation 200 m
Top of Parapet (Elevation) 201.00 m
Crest Length 250.00 m

**APPROACH CHANNEL (HEAD WORKS STRUCTURE)**

Bottom Elevation
Ogee Bays, 1, 2 and 3 160.00 m
Ogee Bays, 4, 5, 6 and 7, Orifice Bays And Power Intake 145.00 m

**SPILLWAY (OGEE AND ORIFICE)**

Chute (Divided into 4 channel by 3-1.75-m thick intermediate training walls and Is enclosed by 2 exterior retaining walls)

Length (in plan) 287.00 m
Width 180.00 m
Floor Slope
  Downstream 100 meters 15 %
  Remaining Upstream Section 3 %

**FLIP BUCKET**

Type With Serrations
Bucket Radius 35 m
Bucket Invert Elevation 122.50 m
Bucket Tooth Radius (starting at Elevation 124.611 m) 16 m
Bucket Tooth Lip Elevation 130.469 m
**PLUNGE POOL AND OUTLET CHANNEL**

- **Pool Bottom Length (from apron wall):** 150 m
- **Pool Bottom width:** 180 m
- **Pool Bottom Elevation:** 80 m
- **Side Slopes:** 1 to 1 with berms at 20 & 15 m intervals

**DIVERSION TUNNELS AND LOW LEVEL OUTLET GATE**

- **Type:** Circular with Concrete Lining
- **Number and Diameter (35 m on centers):** 2-12 m diameter
- **Average Length:** 630 m
- **Upstream Invert Elevation (both tunnels):** 100 m
- **Downstream Invert Elevation (both tunnels):** 96 m
- **Maximum Design Discharge (both tunnels operating with upstream water Surface Elevation at 164 m):** 5,500 m$^3$/s

Note: Both Tunnels were plugged with concrete, 25 meters long. But Tunnel No. 1 plug has a 3 meters x 3 meters opening which is provided with two vertical slide gates in tandem. The invert elevation of the opening is 99.15 meters.

**MAGAT – BALIGATAN CONNECTION CHANNEL**

- **Bottom Length:** 550 m
- **Bottom Width:** 10 m
- **Bottom Elevation:** 158 m
- **Side Slopes:** 1.5:1

**BALIGATAN OUTLET WORKS**

- **Type:** Circular Concrete Conduit
- **Number and Diameter:** 1-3 m diameter
- **Total Length:** 270 m
**INTAKE STRUCTURE**

Type: Concrete Block-6 m wide x 11 m long x 13.7 m high, provided with trash rack at the upstream face, bulkhead slot and bulkhead

Intake Opening: 3 m x 3 m

Approach Channel Elevation: 154.75 m

Intake Sill Elevation: 155.96 m

**VALVE CHAMBER STRUCTURES**

Type: Concrete Block – 11.7 m wide x 14 m long x 13.5 m high – under the Baligatan Dam impervious core

Type of Valve: Spherical Valve

Number and Size of Valve: 1 – 2.20 m

Elevation of centerline of valve: 156.10 m

Steel Pipeline (from valve chamber to control structure, housed by the concrete conduit and supported by steel cradles)

Diameter: 2.20 m

Length: 132.654 m

**CONTROL STRUCTURES**

Control: 2-high pressure slide gates with guard gates

Size of Gates: 1 m x 1.6 m

Maximum Discharge: (gates fully opened and reservoir level is at elevation 193 m) 32 m³/s

**STILLING BASIN**

Type: USBR Typical Stilling Basin Type II (provided with a dividing wall)

Basin Invert Elevation: 147.8 m

Total Basin Length: 35.00 m

Maximum Tailwater Elevation: 154.83 m
CHAPTER 2

ORGANIZATION

2.1 MARIIS AND THE DRD (DRD)

The organizational structure of MARIIS and DRD are shown in Figures 2.1 and 2.2, respectively. The integrated system is headed by an Operations Manager while the DRD is headed by a Division Manager (DRD Manager).

The DRD has four Sections with all heads of Section reporting directly to the DRD Manager. They are:

- Civil Works Section
- Electrical/Mechanical Section
- Instrumentation and Flood Forecasting/Warning Section
- Watershed Management Section
- Administrative Section

A Dam Safety Committee shall be organized by NIA CO to periodically evaluate the performance of the Magat Dam Complex. With the recent privatization of NPC Magat, an Oversight Committee and a Technical Working Group (TWG) was also organized to define their respective functions in the Memorandum of Agreement between the NIA and SN Aboitiz.

2.2 ASSIGNMENT OF RESPONSIBILITIES

2.2.1 OPERATIONS MANAGER, MARIIS

The Operations Manager (OM) is responsible for the overall direction, supervision and coordination of the operation, management and maintenance activities at the Magat Dam and appurtenant structures, reservoir and resettlement areas, as well as the operation and maintenance of the four (4) irrigation districts within the service area of MARIIS. For technical support, the OM is being supported by four staff divisions namely, the Engineering and Operation Division (EOD), Equipment Management Division (EMD), Institutional Development Division (IDD) and the Administrative and Finance Division.

2.2.2 MANAGER, DRD

The DRD Manager is responsible for the direction and control of all operational and maintenance aspects of the Magat Dam Complex, reservoir, watershed and resettlement sites. For normal operations, such as routine water release for irrigation and power, he is
guided by instructions from the Operations Manager. However, in times of emergencies, such as typhoons, floods, earthquakes and extremely unusual occurrences where the safety of the dam is at stake, he has the authority to make immediate decisions and order appropriate actions. Decision on abnormal operations and maintenance problems, which do not constitute an emergency, but which require special study by experts or special allocation of funds for solution, shall be the responsibility of the Central Office, Quezon City.

The DRD Manager is responsible for implementing the Emergency Action Plan, including alerting civil and military authorities, whenever the safety of any of the dams is threatened or whenever it is necessary to open the spillway to release flood flows which can not be passed through the turbines.

The DRD Manager shall prepare a hierarchy of succession in his absence who shall temporarily take over the management and supervision of DRD during normal operation clearly specifying the extent of the delegated authority to ensure the normal functioning of the DRD. The order of succession shall be as follows:

1. Civil Works Section
2. Electrical/Mechanical Section
3. Instrumentation and Flood Forecasting/Warning Section

In the event of emergencies however, the hierarchy of succession shall be as follows:

1. Instrumentation and Flood Forecasting/Warning Section
2. Electrical/Mechanical Section
3. Civil Works Section

### 2.2.3 CIVIL WORKS SECTION

The Civil Works Section is responsible for the maintenance of the embankments and structures including clearing and maintenance works of the Magat Dam, Baligatan Dam, MARIS Diversion Dam and Baligatan Diversion Dam. The operation and maintenance of campsite facilities, maintenance of access roads and maintenance of heavy equipment and service vehicles are also the responsibility of the Civil Works Section.

### 2.2.4 ELECTRICAL/Mechanical Section

The operation and maintenance of all electrical and mechanical equipment at the Magat Dam Power Intake, Spillway, Headworks & Drainage Galleries, Baligatan Outlet
Works and Power Plant, MARIS Diversion Dam and Baligatan Diversion Dam are the responsibility of the Electrical/Mechanical Section. It is also responsible for the operation and maintenance of the power transmission and distribution systems in the Magat Dam Complex and the transmission line of Baligatan Hydroelectric Power Plant.

2.2.5 INSTRUMENTATION AND FLOOD FORECASTING AND WARNING SECTION

This Section is responsible for the collection of all data from instrumentation at the Magat Dam Complex. They will collect data, record, pilot, file, make calculations, analyze and make regular reports. Hydrological and micro seismic data also are collected and processed through this section. This section is responsible for immediately bringing to the attention of the DRD Manager any unusual occurrence or abnormal trend related to the instrumentation or behavior of the structures. THE DRD MANAGER SHALL REPORT THE MATTER BOTH TO THE ADMINISTRATOR, NATIONAL IRRIGATION ADMINISTRATION CENTRAL OFFICE, QUEZON CITY AND TO THE OPERATIONS MANAGER, CAUAYAN CITY, ISABELA BUT SHALL IMPLEMENT ON HIS OWN INITIATIVE WHATEVER INTERIM MEASURES ARE NECESSARY TO ENSURE THE SAFETY OF THE DAM.

Monitoring of sedimentation rate of the Magat reservoir, operation and maintenance of the Flood Forecasting and Flood Warning System (in coordination with PAGASA), coordination with LGUs, RDCC and other concerned agencies/organizations in cases of emergencies are also the responsibilities of the Instrumentation and Flood Forecasting and Warning Section.

2.2.6 WATERSHED MANAGEMENT SECTION

This Section is responsible for the management, protection, development and rehabilitation of around 7,500 hectares of the Magat watershed immediately upstream of the Magat Dam as well as the maintenance of plantation roads. The Section is also responsible in the assessment and monitoring of the extent of watershed/forest denudation beyond its protected area brought about by illegal activities including the preparation of plans and program of works necessary to ensure the adequate protection of the entire Magat watershed.

2.2.7 ADMINISTRATIVE SECTION

The Administrative Section is responsible for property and procurement, cashing, personnel and records, security and spare parts inventory control. The proper implementation of existing Civil Service rules and regulations and Memorandum Circulars relative to Administrative matters is also the responsibility of this Section.
2.3 OTHER AUTHORITIES

The operations and maintenance of the Magat Dam Complex facilities affects and are affected by the activities of other agencies, government or private. As a result, exchange of information and coordination between the National Irrigation Administration and these organizations are necessary. Following is a list, not necessarily all inclusive, of the more important agencies with which communication shall be established and maintained on a regular basis. They have been grouped according to the principal topics of mutual interest.

a. EMERGENCY ACTION PLANNING, TYPHOONS AND FLOOD FORECAST, AND DISASTER RELIEF

- Office of Civil Defense
- Provincial Governors
- Municipal/City Mayors and Barangay Chairmen
- PAGASA
- Philippine National Police (PNP)
- Department of Public Works and Highway (DPWH)
- Department of health (DOH)

b. POWER GENERATION AND TRANSMISSION
- National Power Corporation (NPC)
  - PSALM
  - Stratkraft Norfund – Aboitiz Power, Incorporation (SNAPI)
  - TRANSCO
  - ISELCO I
  - IFELCO

c. WATERSHED AND RESERVOIR USES

- DENR
- NPC
- BFAR
- DILG/LGUs

d. ACCESS ROADS AND HIGHWAYS
- DPWH
2.4 REPORTING PROCEDURES

2.4.1 REGULAR MONTHLY OPERATIONS AND MAINTENANCE REPORTS

A report covering the operations and maintenance activities of each calendar month shall be submitted to the NIA-Central Office not later than the 15th day of the following month. The report submittal routing and number of copies shall be as follows:

TO : The Assistant Administrator
     Systems Operations and Equipment Management
     NIA-Central Office, Quezon City
     -Original Copy

Through: The Operations MARIIS
         Minante 1, Cauayan City, Isabela
         -1 copy

2.4.2 INSTRUMENTATION AND DAM SAFETY REPORT

The Dam Safety Committee shall conduct dam safety evaluation and routine inspection of the whole Magat Dam Complex at least once a year. It shall likewise inspect the dam complex after the occurrence of critical events like heavy run-off, severe rain storm and earthquake. A report on the result of the inspection shall be submitted to the NIA-Central Office not later than 15 days after the evaluation period. The report shall be submitted directly to the NIA ADMINISTRATOR a copy of which furnished the MARIIS OM.

2.4.3 UNUSUAL OCCURRENCE OR EMERGENCY REPORTS.

UNUSUAL OCCURRENCES OR EMERGENCIES SHALL BE REPORTED TO THE OPERATIONS MANAGER WHO SHALL REPORT THE SAME TO THE NIA ADMINISTRATOR IMMEDIATELY BY THE MOST EXPEDITIOUS MEANS APPROPRIATE TO THE NATURE OF THE EVENT.

Radio and telephone reports shall be followed by written reports giving the details of the causes, actions taken and results of the occurrence or emergency. The written report should be submitted not more than two days following the occurrence of such events or as soon thereafter as possible.

2.5 POLICIES AND GUIDELINES

The policies and guidelines normally needed for the safe and satisfactory operations and maintenance of the Magat Dam Complex are presented in this Manual. However, whenever there are new policies and guidelines adopted, the National Irrigation
Administration CO will disseminate these by the issuance of separate instructions to the MARIIS OM who in turn will provide a copy to the DRD Manager.
MAGAT RIVER INTEGRATED IRRIGATION SYSTEM
ORGANIZATIONAL CHART

OPERATIONS MANAGER

OM's STAFF

ENGINEERING AND OPERATION

EQUIPMENT MANAGEMENT

INSTITUTIONAL DEVELOPMENT

ADMINISTRATIVE DIVISION

DISTRICT I

DISTRICT II

DISTRICT III

DISTRICT IV

DAM AND RESERVOIR DIVISION
CHAPTER 3

GENERAL PROJECT AND SYSTEM INFORMATION

3.1 PURPOSE OF THE PROJECT

The Magat River Multipurpose Project was implemented purposely to utilize the flows of the Magat River to provide dependable water supply for irrigation and for power generation.

The present benefits are:

For Irrigation = provide year-round irrigation requirement for almost 85,000 hectares of riceland tilled by almost 77,000 farmers which has the potential of producing 13,725,249 cavans of paddy per annum or 8,921,412 cavans of rice (446,071 metric tons @ an average milling recovery of 65%).

Fish Production = 1,548 tons of tilapia per year (CY 2006 data) from almost 631 fisherfolks.

Power = the 360 MW MHEPP privatized in April 25, 2007 and now owned and operated by SN Aboitiz Inc April 25, 2007) with a ten-year annual average production of 900,000 MW.

= the 6 MW BHEPP with a ten-year annual average production of 30M kw which serves the pumping stations in MARIIS and NIA Region 2.

The project area includes the service area of the two existing irrigation systems, namely, MARIS AND SIFRIS, and these, together with the additional area for irrigation made possible by the construction of the Magat Dam to store water together with all the appurtenant facilities and structures, brought the present firmed up service area to 84,795 hectares. The Magat Hydroelectric Power Plant (MHEPP) constructed below the Magat Dam has an initial installed capacity of 360 megawatts with a provision to increase its capacity to 540 megawatts. (With the government’s program to privatize the generating assets of the NPC as mandated by the EPIRA LAW, the ownership of the MHEPP was transferred from the NPC to the SN-ABOITIZ effective April 25, 2007). A 6-megawatt power plant was also constructed on the outlet works of the Baligatan Dam and this is being owned and operated by the NIA.
3.2 THE MAGAT AND BALIGATAN DAMS

3.2.1 GENERAL

The Magat River has a drainage area of 4,143 square kilometers. The watershed includes mountains rising to altitudes of 3,000 meters and is subject to monsoon climate. As a result, total runoff from the catchment is extremely variable with an annual average of 200 cubic meters per second but an average monthly minimum of 27 cubic meters per second in February and average monthly maximum of 1,060 cubic meters per second in October. In addition, short duration monsoon floods are frequent. The maximum flood peak of record (1971) in the Magat river at MARIIS DAM was estimated at 20,000 cubic meters per second.

The Magat Dam is a major structure by world standards. The embankment dams contain 18 million cubic meters of fill materials, and there are 1 million cubic meters of concrete in the headworks and spillway. The spillway is designed to pass a flood of 30,600 cubic meters per second which makes it one of the largest in the world. The dam is situated in a seismic area, quite close to potentially active faults. The concrete structures were designed for a peak ground acceleration from earthquake forces of 0.5 gravity. The large flood and the high earthquake forces posed many special problems in the design and detailing of the Dam and its appurtenances.

Impounded water in the reservoir is released through the outlet facilities at two points along the dam as follows:

- Through the MHEPP where water use for power generation is re-regulated for irrigation at the MARIS Dam located some 6 kilometers downstream of the Magat Dam.

- Through a spherical valve under the Baligatan Dam which passes water to the Baligatan Power Plant and then discharges to the Baligatan Creek. This water is then diverted at the Baligatan Diversion Dam to irrigation the 9,025 and 2,681 hectare-service area of the South High Canal and the Oscariz Main Canal, respectively.

In the event that the irrigation diversion requirement (IDR) cannot be passed through the MHEPP, it can be passed through the Ogee Spillway with the reservoir above 174 m or through the Orifice Spillway with the reservoir between 174 m and 147 m.

The Magat Dam comprises of a concrete headworks and an earth and rockfill embankments with a total crest length of 4,160 meters and a maximum height of 114 meters. The concrete Headworks are located on the north bank of the river and these contain most of the operating elements of the Magat Dam Complex. At the headworks, there is an Ogee Crest Spillway structure with seven large Radial Gates which in times of flood, release water down the spillway chute where it is thrown into the air by the flip...
bucket and thence into the plunge pool and channel. There are also two orifice spillway gates at a lower level. The Orifice Gates are provided to:

- Enable the reservoir to be drawn down in cases of extreme emergency.
- Assist in passing large flood flows through the spillway.
- To enable irrigation water to be released in the event of the power station being completely closed down with the reservoir below elevation 174.00 meters.

The concrete Power Intake structure contains six conduits connection to the penstocks which convey water to the hydroelectric plant. Each conduit is controlled by a gate at its upstream end and conduits 5 and 6 have steel bulkheads welded to their downstream ends at present. The bulkheads are necessary because penstocks 5 and 6 have not been constructed at this time.

A Traveling Gantry Crane is stationed on top of the Headworks. This crane is used during the maintenance of gates and equipment. Under the embankment on the right bank of the river are two 12.0 meter diameter tunnels which were used for diverting the river around the damsite during construction. Tunnel 2 was completely plugged with concrete but Tunnel 1 has 3.00 meter square outlet built into its concrete plug. This outlet was used to pass river flows during the time that the plug in tunnel 2 was being constructed and in controlling reservoir levels during the initial filling. The gates in this outlet were to be opened only in an emergency if there was some reason for drawing the reservoir down below Elevation 147.00. NIA permanently plugged the low level outlet. Even with the low level permanently plugged, the reservoir can still be lowered to about Elevation 147.00 by the use of the orifice spillway gates.

The Baligatan Outlet Works is located at the extreme southern end of the Baligatan embankment. This consists of a conduit which carries water from the reservoir under the embankment and discharges it into the Baligatan Creek, either through the 6 megawatt power station or through the stilling basin. The conduit is a 3.00 meter concrete from the intake to a point under the core of the embankment. At this point a large spherical valve is located and downstream of the valve, water is conveyed inside of a 2.20 meter diameter steel pipeline which is housed inside a concrete tunnel. At the end of the pipe-line (downstream of the embankment), the pipeline divides into two branches: one branch leading to the Baligatan Hydroelectric Plant and the other branch dividing further into two smaller branches. Each of these smaller branches is controlled by slide gates and releases water into the stilling basin which is divided into two separate channels. Thus, complete flexibility in releasing irrigation water is achieved. Water normally passes through the power plant but when this is not operating, or when irrigation water in excess of power plant capacity is required, water is released through either or both of the stilling basin channels.

The general arrangement of the project is shown on the General Area Plan. SK-OM-001.
3.2.2 Watershed

The watershed of Magat Dam is located in the west-central sector of the Cagayan River basin and embraces a total of 4,143 square kilometers. About 60 percent of the entire drainage area is in Nueva Vizcaya, 33 percent in Ifugao and the remaining 7 percent in Isabela. It is bounded by the Caraballo Mountains on the south, which rise about 1,000 meters above mean sea level. The western boundary of the basin is the Cordillera Central Mountain Range rising to over 2,200 meters above mean sea level. To the east lie the Sierra Madre Mountains and north is the Babuyan Channel.

All rivers within the Cagayan basin drain ultimately into Babuyan Channel. The Magat River is the largest tributary in the Cagayan basin river system. It is about 150 kilometers long from its upper reaches in Nueva Vizcaya to its confluence with the Cagayan River in Naguilian, Isabela.

The Magat River has three tributaries while the Cagayan river has 18 tributaries as shown below:

<table>
<thead>
<tr>
<th>Left side (facing downstream)</th>
<th>Right side (facing downstream)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Magat River</td>
<td>1 Diduyun River</td>
</tr>
<tr>
<td>Sta Cruz River</td>
<td>2 Dibuluan River</td>
</tr>
<tr>
<td>Ibulao River</td>
<td>3 Dumatata River</td>
</tr>
<tr>
<td>Alimit River</td>
<td>4 Ganano River</td>
</tr>
<tr>
<td>2 Sifu River</td>
<td>5 Sinalugan River</td>
</tr>
<tr>
<td>3 Mallig River</td>
<td>6 Diadi River</td>
</tr>
<tr>
<td>4 Afusing River</td>
<td>7 Dinabungan River</td>
</tr>
<tr>
<td>5 Chico River</td>
<td>8 Madalan River</td>
</tr>
<tr>
<td></td>
<td>9 Ilagan River</td>
</tr>
<tr>
<td></td>
<td>10 Binacan River</td>
</tr>
<tr>
<td></td>
<td>11 Tumauini River</td>
</tr>
<tr>
<td></td>
<td>12 Pinacanauan de Cabagan River</td>
</tr>
<tr>
<td></td>
<td>13 Pinacanauan River</td>
</tr>
</tbody>
</table>

The proportion of the Magat Watershed area to the entire drainage area of the Cagayan River at some selected points is shown below:

<table>
<thead>
<tr>
<th>Point</th>
<th>Magat Watershed</th>
<th>Cagayan Watershed</th>
<th>Total Watershed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hectares</td>
<td>% of total</td>
<td>Hectares</td>
</tr>
<tr>
<td>Gamu</td>
<td>5,113</td>
<td>35</td>
<td>6,633</td>
</tr>
<tr>
<td>Tuguegarao</td>
<td>4,213</td>
<td>21</td>
<td>15,847</td>
</tr>
</tbody>
</table>
3.2.3 RESERVOIR

The full supply level of the Magat Reservoir is Elevation 193.00 meters and the minimum operating level is Elevation 160.00 meters. At Elevation 193.00 meters the area of the Reservoir is 4,500 hectares. Between elevation 193.00 and 160.00, meters, the useful storage in the reservoir is 810 million cubic meters. The reservoir volume and Area Curves are shown on Drawing SK-H-005 contained in Volume 2. The average annual stream flow of the Magat river is 6,700 million cubic meters. The reservoir shall be operated such that it returns to its full supply level at the end of each year.

The Magat reservoir was designed to have an economic life of 100 years with the estimated average sedimentation rate of 5.5 million cubic meters/year (mcm/yr) or equivalent to the catchments sediment yield of about 20 tons/ha-yr. After 100 years, it is estimated that the sediment in the upstream face of the dam has already reached the invert level of the power intake which means that by that time, the dead storage is full and thus power generation shall no longer be possible. NIA implemented the Watershed Management and Erosion Control Project (WMECP) in 1985 to reforest about 7,500 hectares immediately upstream of the reservoir. After the WMECP project, a Watershed Management Section was attached to the DRD to oversee the plantation. This small group, however, can not cope up with the enormous responsibility of maintaining the plantation much more increasing the area to be reforested. NIA therefore has no option but to enter into an agreement with the Department of Environment and Natural Resources (DENR) to jointly protect the Magat watershed.

On the other hand, a system of sediment ranges has been established to monitor sediment deposition. The concerns relating to sedimentation are:

- the rate by which sedimentation reduces the live storage capacity of the reservoir,
- the build-up of river beds in the major tributaries of the Magat River at the upstream end of the reservoir thus causing more extensive flooding than what occurs at present. The area of greatest concern is the Bagabag plains.

The purpose of the sediment range system is to monitor the actual sediment deposition in the reservoir and the tributaries. If the actual sedimentation rate is greater than the estimated 5.5 million cubic meters per year, special measures in addition to on-going erosion control programs are to be implemented to preserve 50 year economic life of the reservoir.

A sediment range is basically a surveyed cross-section of the river valley. The change in the cross-sectional areas obtained in a resurvey after a period of time indicates the rate of sedimentation. The sediment range system for the reservoir and tributary rivers is shown on drawing 1187-F-H-2302.
3.2.3.1 The Magat Reservoir after 22 years of Operation

NIA-MARIIS-DRD conducted series of hydrographic surveys (1998, 1999, 2001, 2002, 2004 and March-April 2005) to determine the actual rate of sedimentation rate in the Magat reservoir. The findings are alarming as shown by the following data:

- total volume of sediments deposited = 301 MCM
- volume of sediments in the live storage = 202.7 MCM
- volume of sediments in the dead storage = 98.30 MCM
- remaining storage capacity (1,113 - 301) = 812 MCM
- remaining capacity in the live storage (963 - 202.7) = 760.3 MCM
- remaining capacity in the dead storage (150 - 98.3) = 51.7 MCM

The above data indicates that the average rate of sedimentation is at an alarming rate of 20 MCM/yr or about 3.6 times the design rate of 5.5 MCM/yr.

The following problems were identified:

- unabated catchment degradation mainly due to slash and burn farming and logging
- severe erosion
- massive landslides triggered by the 1990 earthquake resulting to heavy siltation
- portion of the main reservoir and its adjacent areas which are supposed to be restricted areas are now inhabited mostly by fish cage operators, fishermen and their families and their soil cultivation and related activities increase erosion.

The recommended solutions are the following:

- Massive reforestation and other appropriate erosion control measures must be implemented in the catchment area especially in areas with high soil erosion such as the kainingin farms and open grasslands. The participation of concerned government agencies like NAPOCOR, DENR, LGU, DPWH and even private institutions must be encouraged.
- The huge volume of sediment deposits in the upper reaches of the Magat, Sta Cruz and Matuno rivers are threats to the economic life of the Magat reservoir because of the impending transport of these loose soil materials into the lower reaches of the rivers which may eventually deposited to the Magat reservoir. Structural measures to control the transport of these materials like sabo dams, check dams, gabions and the likes must be constructed along or across the rivers channel. Likewise, the rehabilitation activities of the DPWH and LGUs where the sediments deposited in the river are being extracted and used to reclaim low lying areas along the river must be expanded.
- In anticipation of a possible last option, at this early, a technical study on the feasibility of desilting the entire reservoir must already be started to determine its cost, the most appropriate scheme, its environmental
and protection requirements, social impacts and the disposal of the concomitant sludge.

- The necessity of relocating or even ejecting people living in the watershed/reservoir restricted areas

The non-implementation of the above cited recommended solutions was mainly due to lack of funds. The JICA report of February 2002 estimated a cost of P5 billion pesos for the reforestation activities and another P5.47 billion pesos for the erosion control structures alone.

Norconsult AS was engaged in August 2007 by SN Aboitiz to do a Sedimentation Monitoring Plan for the Magat Reservoir, a part of The Magat River Multipurpose Project. The purpose of the Sedimentation Monitoring Plan is to provide reliable information on sediment inflow, sediment outflow and sediment deposition patterns in the reservoir. This plan will enable SN Aboitiz to estimate future development in the reservoir more accurately, detect changes in sediment inflow regime and plan and evaluate active sediment handling measures.

In addition to present situation the report discusses and presents the following issues for the Sedimentation Monitoring Plan:

- Future sedimentation surveys
- Sediment sampling
- Reservoir sedimentation modeling

The summary of the recommended measures by Norconsult AS is listed below:

1. Ensure regular embankment maintenance includes control of vegetation growth on the upstream and downstream faces of all embankments.
2. A diver inspection of the submerged plunge pool should be carried out to observe current conditions.
3. Consideration should be given to flushing drain holes in galleries which are affected by sludge deposits to enhance their efficiency.
4. Regular inspection of the diversion tunnels downstream of the plug should be carried out to confirm their integrity, including provision for safe access.
5. A formalized dam inspection procedure should be established and followed for the dam including individual check sheets for specific inspection types.
6. A formalized system of periodic dam status reporting and recording should be established and followed.
7. Consider development of an electronic database for instrumentation and inspection data, and enter historical data into the database.
8. Update the Operation and Maintenance Manual to reflect the current management and organization structure for the dam complex.

9. Revamp the regular reporting procedures for the dam, especially instrumentation and dam safety, and ensure the reporting procedures are complied with.

10. The Emergency Action Plan for the dam should be updated to be consistent with modern documents, matching the current organizational structure for the dam, and local government/emergency agencies. Practice turns on the EAP should also be carried out to ensure responsible parties fully understand their roles and requirements. Updated dambreak assessment should also be carried out as part of the EAP to identify potential areas of inundation from various events.

11. Given the improvement in knowledge of active faults in the region and experience from the 1990 earthquake, an updated seismic risk assessment should be carried out for Magat Dam. This should include mapping/interpretation of local faults and regional faults as necessary, taking advantage of new aerial and satellite photography. The study should include production of peak ground accelerations and response spectra at the dam site for the Maximum Credible Earthquake. Vertical components of the earthquake should also be investigated. Use should be made of available earthquake data in the review.

12. Depending on the results of Item No. 11, review the ability of the embankment and concrete gravity sections to sustain the expected maximum credible earthquake.

13. Further data on core and filter gradings should be sought from construction records and a comprehensive assessment of filter compatibility should be carried out.

### 3.2.4 EMBANKMENTS

The embankments of the Magat Dam consist of the following: the Main Embankment, the North Embankment between the Spillway and the left abutment, the North Baligatan Dyke, the Baligatan Embankment and the South Baligatan Dyke which closes the embankment at the right abutment.

The dimensions of these embankments, dams and dykes are:

<table>
<thead>
<tr>
<th>Embankment</th>
<th>Length</th>
<th>Maximum Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Dam</td>
<td>300</td>
<td>35</td>
</tr>
<tr>
<td>Magat Dam</td>
<td>1000</td>
<td>114</td>
</tr>
<tr>
<td>North Dyke</td>
<td>1500</td>
<td>30</td>
</tr>
<tr>
<td>Baligatan Dam</td>
<td>700</td>
<td>50</td>
</tr>
<tr>
<td>South Dyke</td>
<td>350</td>
<td>30</td>
</tr>
</tbody>
</table>
The embankment dams and dykes have impervious cores of highly weathered terrace gravel supported by zones of rock fill and competent river gravel. Wide filter and drainage zones are provided on the downstream side of the core. A wide transition/filter zone is provided on the upstream side between the core and the rockfill. A zone of riprap is provided on the upstream face to protect against wave erosion and a zone of large size rock is placed on the downstream face to prevent damage by surface runoff.

A comprehensive network of instrumentation has been installed beneath and within the embankments to monitor their performance. This instrumentation comprises devices for measuring seepage, pore water pressures, settlements, deflections, stresses, strains, and earthquake induced acceleration. Details are given in Chapter 6.

### 3.2.5 GROUT CURTAIN

Throughout the length of the embankment and the concrete Headworks, and for 100 meters beyond each end, the foundation rock was cement-grouted to reduce the amount of leakage through the foundation. A three line curtain, with lines at 3 meters on centers, was provided and this was increased to five lines where the embankment was more than 50 meters high. The depth of the grout curtain is generally 70% of the height of the embankment at the point. The grout curtain effectiveness is checked throughout the life of the dam by monitoring the instrumentation that is installed below the embankments.

### 3.2.6 EMBANKMENT/CONCRETE INTERFACES

There are two interfaces between the embankments and the concrete headworks structure: one on the right side of the Power Intakes and the other on the left side of the Spillway. These interfaces, which are about 65.00 meters and 25.00 meters high, respectively, are close to being the highest yet constructed. They have been carefully designed to maintain good contact between the core of the embankment and the concrete faces under all loading conditions. The interfaces are vulnerable parts of the dam and detailed instrumentation has been installed in these areas.

### 3.2.7 SPILLWAY HEADWORKS

#### a. Ogee Bays

The seven ogee openings are equipped with radial gates each 16.50 meters by 20.00 meters high. The gates are operated by chain hoists mounted on the spillway piers. One set of stop logs in six sections is provided to allow one gate bay at a time to be dewatered for maintenance of the gate. The stop logs are inserted in the slots upstream of the gates. The stop logs are handled by the headworks gantry crane and the stop log grappling beam.

There are contraction joints through the center of each pier which theoretically make each gate bay a separate structure. The joints are sealed by a pair of water stops with asphalt seal between them.
b. **ORIFICE BAYS**

The two orifice sections are equipped with radial gates, each 6.00 meters wide by 12.50 meters high. Each gate is operated by an electro-hydraulic cylinder hoist mounted on the platform between piers. A stop log in four sections is provided to allow for the dewatering of one gate at a time for maintenance. The stop logs are handled by the Headworks Gantry Crane and the orifice lifting beam. The stop logs are stored in the two stop log slots and the two storage slots.

c. **GATE CONTROL HOUSE**

A Gate Control House has been constructed on the left interface structure. From this point, the Ogee Spillway Gates can be operated by remote control. The Power Intake Closure Gates and Orifice Spillway Gates positions are relayed to indicators in the Gate Control House.

d. **STANDBY GENERATOR HOUSE**

A stationary diesel engine driven electric generator to provide emergency power to the Headworks is installed in a separate generator house a short distance to the left of the Gate Control House.

A portable diesel-generator unit that can provide emergency power to any one Ogee Spillway Gate is also kept in this Standby Generator House.

e. **SPILLWAY BRIDGE**

The beams for this bridge are precast reinforced concrete and the deck is concrete poured in place. The beams are designed to act as struts between the power intake structure and the left interface. The bridge is designed to carry the maximum wheel loads from the headworks gantry positioned anywhere on the span of the bridge or a truck load of 150% of AASHO loading HS20-S16.

### 3.2.8 SPILLWAY

a. **CHUTE**

The chute is 287.00 meters long in plan and 180 meters wide. The downstream 100.00 meters slopes at 15% and the remaining upstream section has a slope of 3%. The chute is divided into four channels by three 1.75 meter thick intermediate walls and is enclosed by two exterior walls. The three spillway bays accommodate 2, 3, and 2 ogee spillway gates respectively. The orifice spillway is 24.00 meters wide. The intermediate walls are 10 meters high. Two drainage galleries run the full length of the chute at roughly the third points of the chute width. They are connected to the
headworks drainage galleries and continue through the flip bucket to discharge into the plunge pool. The galleries are connected by a lateral gallery halfway down the chute. The chute slab sits directly on the prepared foundation and is underlain by a series of perforated pipe drains. The pipe drains are vented to atmosphere through pipes in the training walls. The chute slab is anchored to the foundation by embedded dowels. The upstream section of the chute slab is 1.00 meter and the downstream section is 1.50 meters thick, the change occurring at the change of the slope.

b. **FLIP BUCKET**

A massive concrete flip bucket with serrations is provided at the downstream end of the chute to throw the water into the plunge pool. The bucket structure is protected by a 1 to 1 sloping concrete apron wall which extend from the bucket to 5.00 meters below the bottom of the plunge pool. The wall is 3.00 meters thick. The radius of the flip bucket is 35.00 meters and the invert of the bucket is at Elevation 122.50 meters. Drains are provided to drain off water which will collect in the flip bucket.

Drainage holes are installed along the upstream face. Half round pipes have been installed to dispose of water from the drainage holes. The lateral gallery intersects the longitudinal galleries which traverse the length of the chute. Access to the lateral gallery is possible from shafts in the exterior walls of the chute.

Piezometers have been installed from the lateral gallery to check uplift pressures on the flip bucket and apron wall.

The apron wall contains weep holes and these are extended as drain holes drilled into rock. The drain holes are lined with perforated PVC pipes. The apron wall is anchored to the rock by dowels.

c. **PLUNGE POOL AND OUTLET CHANNEL**

The plunge pool has its base at Elevation 80.00 meters. The pool bottom extends for 150.0 meters from the apron wall. It is 180.0 meters wide. Side slopes are 1 to 1 with berms at 20.0 meters and 15.0 meters intervals. At its downstream end the plunge pool slopes upwards at 1 vertical to 4 horizontal to meet the outlet channel at Elevation 100.0.

3.2.9 **HEADWORKS POWER INTAKE**

The Power Intake consists of six individual gravity dam blocks each containing a waterway extending into a 5.80 meters diameter penstock, a bulkhead gate shaft, a closure gate shaft, and an equipment room. There is 5.00 meters wide by 5.527 meters high closure gate installed in each closure gate shaft. The gate is operated by an electrohydraulic cylinder hoist. The gate can be raised (Crack operation) to 25 cm against the full unbalanced head. When fully open, the gate can be lowered under flow (Emergency Lower). There is provision for automatic closing in the event of a break in the penstock.
There is one Bulkhead Gate supplied which will allow the unwatering of one gate at a time for maintenance. This bulkhead is handled by the Headworks Gantry Crane and the Bulkhead Gate Grappling Beam.

Trash Racks are installed over each waterway on the upstream face of the dam. These are to prevent large debris from entering the penstocks and turbines. Each penstock waterway is divided into two passages upstream of the gate shafts by a central vertical pier. Each passage is protected by its trash rack, which is in four sections.

The Closure Gate Shafts are raised slightly above the intake deck level to prevent debris, dirt, stones etc. form being knocked into the shaft and thence into the penstock and turbine. The Shaft is open with a protective grill so that air can be drawn into the penstock as it is being emptied.

3.2.10 APPROACH CHANNEL

The Approach Channel serves both the Power Intake and the Spillway. It is set at two levels to suit the topography of the left bank. The approach to the Power Intake, the Orifice Spillway, and bays 4 to 7 of the Ogee Spillway are set at Elevation 145.0 meters. The remaining bays (1, 2 and 3) are set Elevation 160.0 meters.

3.2.11 GALLERIES AND ACCESS POINTS

Refer to drawing 1202-G-1022 and 1202-G-1023

a. HEADWORKS

Access to all upper level galleries and platforms, the Concrete Headworks, except for instrumentation galleries in the interfaces, is from the centrally located Orifice Spillway area and does not require the lifting of shaft covers. Access to the foundation drainage gallery (within the structure) and thence to the drainage gallery in the foundation can be via the stairs from the upper level gallery in the Ogee Spillway or from the penstock area downstream of the Power Intake. There is also a shaft in the Power Intake structure which connects these two drainage galleries. Access to the interface instrumentation galleries is via personnel access shafts which are provided with steel covers. Sections of intermediate platforms are removable to allow small equipment to be lowered to the instrumentation galleries.

Access is provided from the Orifice Spillway platform to a walkway along the full length of the Ogee Spillway Gate Trunnion Support Beams.

Personnel access shafts (1800 millimeters x 1000 millimeters) with ladders and landings, and equipment access shafts (1800 millimeters x 2000 millimeters) are located at several positions across the Headworks structure.

Personnel access shafts have been provided for routine inspection of joint drain operation and waterstop leakage. The equipment access shafts have been provided to
allow drilling and grouting equipment to be lowered to the foundation drainage gallery for re-drilling of drain holes and for remedial grouting. In other contraction joints in the water retaining structures, a 1.00 meter square inspection shaft is provided downstream of the waterstop. Besides providing joint drainage in the event of waterstop failure, this allows inspection to determine the origin of significant leakages. A man has to be lowered down the shaft to make the inspection.

EXHAUST FANS MUST BE SWITCHED ON AND OPERATED FOR 15 MINUTES BEFORE ENTERING THE INSTRUMENTATION GALLERIES AT THE LEFT AND RIGHT INTERFACES; ESPECIALLY AT THE RIGHT INTERFACE GALLERIES WHERE HIGHLY TOXIC MERCURY VAPORS MAY BE PRESENT.

b. FOUNDATION

Foundation Drainage Galleries are located in both abutments of the Magat Dam, and beneath the Concrete Headworks and North Embankment. A concrete floor has been provided in all galleries. On the left bank, access is provided to Drainage Gallery K through a concrete culvert which emerges at the downstream side of the switchyard on the powerhouse side. On the right bank, access is provided via Drainage Gallery E whose portal is located directly south of the switchyard. Access to Gallery K is also provided at its north end by Gallery L. Lighting and ventilation have been installed in the galleries.

3.2.12 DRAINAGE

Seepage of water through the foundation is controlled by intercepting the seepage with drain holes which discharge the water into the drainage galleries. These galleries carry the water downstream of the dam where it is discharged safely. The drain holes also serve to relieve uplift pressures which may exist beneath the concrete structures.

Beneath the embankment dams, the drainage gallery is located at some distance downstream of the core. Beneath the concrete headworks, it is located a short distance downstream of the grout curtain.

Additional drainage galleries have been constructed on each side of the low angle shear zone under the power intake structure.

The cross-sections of the galleries are such that the galleries are of adequate size to operate a drill rig. Drain holes have been drilled upwards and downwards from the galleries to intercept seepage which finds its way through or around the grout curtain, or direct from the abutments.

Seepage pressure drain holes have been installed along the downstream toe of Baligatan Dam and Dyke in areas where shears or faults cut the foundations and where uplift pressures and considerable seepage was noted.
3.2.13 DIVERSION TUNNELS AND LOW LEVEL OUTLET GATES

Two 12.00 meter diameter circular tunnels were provided at Magat Dam beneath the right abutment to divert the river flow around the construction area. Both tunnels are lined with concrete, Tunnel I being about 670 meters long and Tunnel 2 about 590 meters long.

Each tunnel in turn was closed by steel gates at the intakes to enable 25 meters long concrete plugs to be constructed in the tunnels at the point where the dam grout curtain intersects the tunnels.

The steel gates were recovered for use elsewhere. The Tunnel 2 plug has no opening in it but the Tunnel 1 plug has a 3.00 meters square opening, the downstream portion of which was steel-lined and equipped with two vertical slide gates. These gates were provided to allow irrigation and construction water releases during the period when the reservoir was being initially filled. The gates also provided control over the rate of filling of the reservoir. When the reservoir was initially filled to Elevation 155.00, both gates were closed and not operated again. The gates were not kept in operating condition and after several years, a decision was made by the National Irrigation Administration not to retain the low level outlet. Since the outlet was no longer required, it was permanently plugged with concrete.

3.2.14 MAGAT-BALIGATAN CONNECTION CHANNEL

This channel serves to deliver water from the main reservoir to the Baligatan Outlet Works at low reservoir level. The invert level of the channel is Elevation 158.0 meters. This level allows a discharge of 16 cubic meters per second through the outlet works with the reservoir at its lowest supply level of Elevation 160.00 meters.

The channel shall be surveyed to check for sedimentation at the same time as the reservoir sedimentation ranges are being surveyed.

3.2.15 BALIGATAN OUTLET WORKS

These outlet works are described in para. 3.2.1.

The upstream concrete conduit operates normally under balance water pressure and is only subjected to unbalance loading conditions when the intake stop log has been installed and the conduit has been dewatered. Construction joints have been fitted with waterstops.

The valve chamber is formed in a concrete block. The space between the block and the excavation surface was backfilled with concrete and the block/backfill contact surface was grouted. The concrete access tunnel is accessible via an access hatch with a removable cover and by a door. Construction joints are provided with waterstops.
The steel pipeline is supported on steel cradles, one end of each pipe section being fixed and the other free to slide. The joints are flexible couplings which allow pipe movements. Bifurcations in the pipeline are housed in mass concrete blocks.

The outlet gate house sits on the concrete block containing the outlet gates. All gate controls and remote valve controls are contained within the gate house. Part of the roof can be removed if required for maintenance of the gate hoists.

3.2.16 BALIGATAN POWERHOUSE

In the study phase for the Magat Dam, the installation of power generating features at Baligatan was found to be uneconomical. However, a review in 1991 showed that the Baligatan power is economically feasible if the power is used to power the new pumping station in the irrigation area. A 6-megawatt power plant was constructed downstream of Baligatan Dam and takes its water from the outlet works pipeline immediately upstream of the outlet gates.

Operating and maintenance instructions for this power plant do not form part of this Manual.

3.2.17 POWER SUPPLY

Refer to the following Single Line Diagrams:

SK-OM-002 Powerhouse and A. C. Station Service
SK-OM-003 Power Intake Substation
SK-OM-004 Spillway Substation

Power is delivered the Magat Dam Complex as follows:

a. NORMAL POWER SUPPLY

From the Magat generator bus, power is supplied at 13,000 volts, 3-phase, 60 hertz to the following points:

1. the Power Intake Substation at the south end of the Power Intake Equipment room elevation 196.00 m. The 225-kVA 13.8 kV-480/277V 60 Hertz transformer at this point connects to a Distribution Board Bus where breakers for the Power Intake Closure Gates, Gantry Crane and Lighting are provided. One breaker connects to a 480/240-volt transformer that supplies power for Drainage Galleries I, k and L.

2. the Spillway Substation at the Orifice Spillway Gallery elevation 196.00 m. The 225-kVA 13.8 kV/480-277V 60 Hertz transformer connects to a Distribution Board Bus where breakers for the Spillway Gates, Power Receptacles, Spillway Bridge Lighting, North Dam lighting, and Gallery Lighting are provided.
3. the transformer bank at the building over Drainage Gallery M Access Shaft. These transformers supply power for Drainage Galleries E, F & G, Powerhouse Road, and Instrument Observation Stations at the Main Dam.

4. the pole mounted transformer at the Dam Vicinity Seismic Monitoring Station

Power Supply for Magat Park, and Baligatan Dam and Dyke is drawn from Baligatan Hydroelectric Power Plant.

b. EMERGENCY POWER SUPPLY

Because it is absolutely essential that power must always be available to the Spillway and Power Intake under all circumstances, a 75 KVA emergency Stationary diesel engine-generator set was provided. A Generator House was constructed at the North Embankment Dam just a few meters away from the Left Interface. Power from this set can be fed to each distribution board in the Spillway and Power Intake Substations.

As a supplement, a portable 40 kVA Diesel-Generator Unit is also stationed at the Generator House. In case the Stationary Emergency Diesel-Generator Set fails, this portable Unit can be drawn near the Ogee Spillway Radial Gate to be operated. An auxiliary power receptacle was installed on each gate control cabinet for this purpose.

c. GROUNDING

A completely interconnected system of copper cables has been provided to connect all transformers, lightning arresters, electrical equipment frames and enclosures, penstock liners, gate frames, and other metal equipment that is subject to electrical potential to ground. The grounding system consists of cables laid on the foundation rock beneath the concrete headworks structures. The cable grid is connected to grounding rods which have been embedded in the foundation rock. The grid is also connected to the grounding loop in the floor of the intake equipment room. It is interconnected with the penstock, powerhouse and switchyard grounding systems.

3.2.18 LIGHTING AND POWER OUTLETS

Refer to the lighting general arrangement drawing 1202-E-1405, 1406, 1422, 1423

a. INTERIOR

The lighting power supply is 3 phase, 4 wire, 208/120 volts. Lighting panels are located at the distribution boards inside the spillway and intake substations. The panels are fed by dry type 480-208/120 volt transformers. Incandescent lamps in airtight enclosures are installed in access and drainage galleries and elsewhere that the lighting system is be turned ON/OFF frequently.

b. OUTDOOR
Power supply for lighting of the dam crest and roadway is 3 phase, 4 wire, 480/277 volts directly from the substation distribution boards. The roadway lighting for the Baligatan Dyke and Outlet Works is supplied by the 480/277 volts overhead distribution system. Individual photoelectric controllers are provided for roadway lighting. Mercury vapor lamps are provided for outside lighting.

3.2.19 COMMUNICATIONS

Communication to the Magat Dam Headworks is through the following means:

1. VHF Handheld Transceiver
2. VHF Base Transceiver
3. Cellular Phone
4. NPC PABX Telephone.

3.3 MARIS DIVERSION DAM

This dam is located at Barrio Oscariz about 6 km downstream of Magat Dam. The original dam was constructed in 1957 and had an original service area of 23,500 hectares. About 17,300 hectares was added to the system in 1966. In 1982 an expansion and rehabilitation of the irrigation system was completed. Under this expansion the service area was increased to 75,000 hectares. The expansion area included the Siffu River Irrigation System and extension areas served from the new North Main Canal. The new North Canal was constructed as part of the modifications and raising of the MARIS Dam which was completed in 1982.

The raised MARIS Dam can store about a day IDR for the 75,000 hectares it serves. The crest of the dam was raised to Elevation 102.00 meters, and provisions made for installing stop logs on the crest to enable the MARIS reservoir to be raised to Elevation 105.00 meters. The additional storage is needed to regulate the release from the power plant in periods of high irrigation demand.

3.4 BALIGATAN DIVERSION DAM

The Baligatan Diversion Dam is located on the North Baligatan Creek about 2 kilometers downstream of its junction with the South Baligatan Creek. Its function is to divert water released from the Magat Reservoir, through the Baligatan Outlet Works, into the 11,706 hectares irrigation system. The dam consists of 270 meters of embankment with a maximum height of 13.00 meters, and a concrete dam 13.00 meters high. The concrete dam incorporates the outlets to the Oscariz Main Canal to the north, and to the South High Main Canal. A sluice section controlled by a radial gate is located in the south side of the dam.
CHAPTER 4
RESERVOIR OPERATION

4.1 NORMAL OPERATION

4.1.1 RESERVOIR OPERATING RULE CURVE

The reservoir is presently operated in accordance with an Operation Rule Curve jointly developed by the NIA, NAPOCOR and NWRB in 1985. This rule curve is designed to optimize the utilization of the water stored in the Magat reservoir (Figure 4.1). The operation rule curve sets the minimum month-end reservoir elevations that shall be maintained by controlling reservoir releases through the Magat Hydroelectric Plant (MHEPP) and at the Baligatan Outlet Works (BOW) to ensure water availability for irrigation on a year-round basis. This requires that the reservoir has to be filled up to its full supply level of elevation 193.00 at year-end. During the months of January to May which are normally dry months, water release for irrigation normally exceeds the river flow resulting to reservoir drawdown, however, during the months of June to November, river flow normally exceeds the irrigation requirement and the reservoir re-fills. Spilling of water from the reservoir may mostly occur during October, November and December when the reservoir is at full supply level and inflow into the reservoir exceeds the combined releases made at the MHEPP and at the BOW.

The criteria associated with the Operation Rule Curve are as follows;

a. Under normal condition, the reservoir elevation shall not be allowed to go below the rule curve except during the occurrence of floods where a decision to pre-release was arrived at.

b. As long as the reservoir elevation is above the rule curve, additional water releases for power generation on top of the irrigation diversion requirement (IDR) will be allowed provided that the projected month-end reservoir elevation shall not fall below the rule curve elevation based on a critical analysis to be done by MARIIS.

4.1.2 NORMAL IRRIGATION AND POWER RELEASES

In cases where inflow exceeds the IDR, all water releases, whether for irrigation or for power or for both, shall be made to pass through the Magat and Baligatan Hydroelectric Plants whenever possible to keep or return the reservoir to the rule curve level. As a general rule, NIA-MARIIS shall provide SNAP with the weekly IDR every Friday following each week for the latter’s information and adjustment in their planning. In the event that there is a change in the IDR, NIA shall recompute the weekly IDR for the remaining weeks of the season and provide SNAP a copy of the same.
4.1.3 SPILLWAY RELEASES FOR IRRIGATION

Water for irrigation is released through the spillway gates only when the Magat Hydroelectric Plant is partially or completely shut down. If the reservoir level is higher than elevation 174.00, the releases shall be made through Gates 3, 4 and 5 of the ogee spillway but if it is lower than elevation 174.00, the releases should be made through the orifice spillway.

4.2 FLOOD OPERATION

4.2.1. Flood Forecasting and Warning System

The function of the flood forecasting system is to predict the discharge of the Magat River and its tributaries during floods. With this predicted discharge, the flood volume can be estimated and depending on its elevation at the time of the flood, the reservoir can be drawn down to a level that will provide storage to contain part of the predicted flood volume. Approximately, two-third of the typhoons passing the Magat catchment area has devastating effect and flood forecasting and advance drawdown in accordance with established procedure contained in this manual is necessary to mitigate or prevent flood damage in the downstream areas of the Magat Dam along the Magat River. Conversely, about one-third of the typhoons are too small to require mitigation. Without flood forecasting, no advance drawdown can be done as there is no information on the amount of water that is expected to arrive.

In June 1983, the early flood forecasting system was installed and activated, however, it stopped functioning a few months later because of electronic components malfunction, outside interference with the radio signals, power failure at the repeater station, vandalism and destruction brought by storms and floods. With the help of PAGASA, the flood forecasting system was reviewed in October 1985 and the necessary repairs, upgrading and relocation of some equipment were done.

The present flood forecasting system consists of

1. six raingages and two streamgages strategically located in the watershed area of the reservoir (Figure 4-2) and
2. Flood Forecasting Center located at the DRD office.

The Flood Forecasting and Warning System must be able to monitor data from in real time, however, due to interference, at present data are available only at the Magat Dam. Also, transmission of data from Magat to PAGASA and vice versa is done thru SMS. Aware of the urgent need to modernize the system, PAGASA prepared its modernization program for the entire Cagayan River basin for immediate implementation.

Prior to the issuance of a Presidential directive in December 12, 2006, the MARIIS DRD office undertakes the forecasting of inflow but after the issuance of the said directive, PAGASA came out with a flow chart of activities to be followed in times of floods.
Flow of Activities During Floods

**Monitoring**
- PAGASA
- NIA-MARIIS

**Prediction**
- Forecast rainfall
- Compute inflow using past & present WL of dam
- Run hydro model to convert forecast RR to forecast inflow

**Decision Making**
- (Operate spillway or pre-release?)
- Forecast rainfall / Volume of water
- Downstream condition
- Run hydro model to convert forecast RR to forecast inflow

**Warning**
- Concerned Government Agencies
- LGUs – Isabela & Cagayan
- Public and Media
- SNAP

**Spillway Operation, Flood and Post Flood Operation and Evaluation**
- NIA-MARIIS – from Magat Dam to Naguilian, Isabela
- PAGASA TUG. – from Naguilian, Isabela to Aparri, Cagayan

**Flow of Activities During Floods Diagram**
- Rainfall (watershed)
- Water level of Dam
- Downstream condition
(a) Monitoring of hydro-meteorological data and weather conditions

NIA MARIIS shall be responsible in gathering data from the six (6) rain gauges and two (2) water level recorders within the watershed of the Magat dam. Likewise, it shall also be responsible in computing the inflow into the reservoir as well as in allocating water for irrigation and power generation. On the other hand, PAGASA shall provide NIA MARIIS information on tropical cyclones and other weather conditions so that the latter shall be prepared for the expected flood operation.

Rainfall and river water levels shall be observed based on the following time intervals:

1. Non-Flood season every 12 hours
2. Normal period in the flood season every 12 hours
3. Flood precaution period (if no rain yet) every 3 hours
   (after rain started) every 1 hour
4. Flood precaution period every 1 hour
5. Flood period every 1 hour
6. Post flood period (if still raining) every 1 hour
   after rain stopped every 3 hours

It is necessary that data on water level along the Cagayan river and its tributaries be likewise observed but at present, gauging stations to indicate the flow of the Cagayan River and its tributaries are very limited; also rainfall gauges upstream of its tributaries are scarce or not available. This problem is expected to be addressed once PAGASA’s own plan to upgrade its flood forecasting system for the entire Cagayan river basin shall have been operationalized.

(b) Prediction of rainfall and inflow

Hourly rainfall data shall be supplied by NIA MARIIS to PAGASA from which the latter shall base its forecast of inflows using its hydrologic models (Storage Function Model and Statistical Model). For its part, NIA-MARIIS shall undertake hourly comparison of predicted and actual hourly inflows as well as reservoir water balance analysis during the entire flood operation as additional input into the entire prediction process to supplement PAGASA’s.

Based on the forecasted inflow, the decision to pre-release water shall be made by PAGASA.

Sufficient lead time shall be made available for the pre-release operation. At present PAGASA can provide 24-hour forecast rainfall that is appropriate for the operation of the Magat Dam spillway.
(c) Decision to operate the spillway for pre-release

Pre-release is an important option to take when there is a forecast of big flood in the watershed. It is carried out primarily to increase the storage capacity of the dam in anticipation of the peak flood.

Pre-release is decided when:
- the reservoir water level (RWL) is 190.0 m during the flood season or 192.5 m during the non-flood season
- there is a forecast of moderate to heavy basin rainfall for the next 24 hours

In compliance with the December 12, 2006 Presidential directive, PAGASA shall decide whether there is a need to pre-release. In the event that a pre-release is decided, it shall inform the Magat Dam Office of the volume of water to be released and the time when to start the pre-release. The Magat Dam Office shall likewise inform the Office of the Operations Manager of the decision to pre-release.

(d) Preparation of the Pre-release Plan

Upon receipt of the instruction from PAGASA to pre-release, the DRD Manager shall implement its pre-release plan and directs the Head of the Electrical-Mechanical Section to mobilize other personnel to undertake immediately the following:

1. Check that the power supply for the gate controls and lighting in the area is normal.
2. Check that the gate hoist mechanisms and electrical components are functioning.
3. Check the condition of the Stationary and Portable Diesel-Generators and make necessary tests to ensure its normal operation.
4. Crack open then close each Ogee Spillway Radial Gate.

(d.1) Discharging Plan for Pre-release

The discharging plan for the pre-release shall be prepared in compliance with the following discharge rules:

(a) The discharge through the spillway shall be made only when the capacities of the Magat Hydroelectric Power Plant and the Baligatan Power House reached their full capacity.

(b) The discharge shall be increased gradually within the Allowable Increasing Rate of Dam Discharge in accordance with the following rule:
The rate of discharge from the dam shall be within the Allowable Increasing Rate of dam discharge as shown in Fig. 10 in order to avoid the rapid rise of the water level on the downstream reaches of the river. It is, however, allowed to increase the dam discharge at a rate exceeding this Allowable Increasing Rate of dam discharge provided that the rate of increase is within the rate in the inflow when the inflow is increasing rapidly and such increase in the dam discharge is considered requisite and unavoidable to insure the safety of the dam.

(c) The discharge shall be made within the Allowable Discharge for pre-release of 1,600 m3/s. However, if it is considered requisite and unavoidable to increase the discharge beyond 1,600 m3/s in order to lower the reservoir water level before the expected flood starts, then the discharge may be made within the flood flow of 3,000 m3/s. In case of emergency which may affect dam safety, it is exceptionally allowed to make the discharge higher regardless of the provision hereof.

(d) At the end of the prerelease, the discharge shall be gradually reduced until it becomes equal with the inflow. Thereafter, the initial operation shall be adopted in accordance with the following rule:

**Reservoir Water Level (RWL) Above Discharging Waterlevel**

The discharge given in Table 1 Discharge Curve for Initial Operation less the discharge used for power generation of the Magat Power Plant shall be made from the spillway to keep the reservoir water level at or below the flow regulation starting water level in the flood caution period.

**RWL below Discharging Waterlevel**

When the reservoir water level is below the discharging water level, no dam discharge through the spillway shall be made but the inflow shall be stored in the reservoir for water utilization purpose unless the situation corresponds to one (1) of the following:

1. When the reservoir water level rises above the flood season high water level during the flood season.
2. When the reservoir water level rises above the normal high water level during the non-flood season.
3. When the reservoir water level is lowered to the flood season high water level during the transition time from the non-flood season to flood season.
4. When the pre-release is carried out in accordance with the instruction from PAGASA.

5. When the Initial Operation is carried out to maintain the reservoir water level between the discharging water level and flow regulation starting water level.

6. When it is required and decided to make the discharge through the spillway for irrigation

7. When it is required and decided to make the discharge through the spillway for maintaining the river flow on the downstream reaches

8. When it is required and decided to make the discharge through the spillway for lowering the reservoir water level for inspection and maintenance of the spillway gates, equipment, facilities, structures, etc. in the Reservoir

9. When it is urgently required and decided to make the discharge through the spillway due to any other unavoidable reasons.

(d.2) Alteration of Pre-release Plan

PAGASA shall instruct NIA MAGAT to alter its pre-release plan in case there is change in the course of a typhoon. Upon receipt of the instruction to alter its pre-release plan, NIA Magat shall revise its pre-release plan accordingly.

(e) Warning on Pre-release

It is necessary to warn people who live and work close to the river to move to safer grounds before water shall be released from the Magat Spillway to avoid loss of lives and prevent damage to crops and property.

Before the prerelease, an early warning/notice shall be relayed to all concerned agencies/offices using all available fastest means (radio, TV, phones etc).

Agencies to be notified in case of flood releases are:

1. Office of the NDCC and Civil Defense
2. Office of the Governors of Isabela and Cagayan
3. Office of the concerned Mayors
4. Office of the concerned PNP
5. Radio and TV Stations

Likewise, the system of sirens and public address speakers installed at ten strategic locations in the flood inundation area along the Magat River between MARIIS Diversion
Dam and the confluence of the Magat and Cagayan Rivers shall be activated to warn people in the area before spillway releases are made. The warnings given shall correspond to the urgency and flood zone expected to be affected by the release. The DRD Manager must ensure that the downstream flood warning system is activated. The warning given shall correspond to the urgency and flood zone expected to be affected by the release.

When large quantity releases are to be made, NIA Magat shall implement additional warning procedures as required by the Magat Emergency Action Plan. The Magat Emergency Action Plan is included at the front of this Volume I of the Magat Operations Maintenance Dam Safety Manual.

(f) Adjustment of Discharge

When it is considered necessary during the pre-release to stop or decrease the discharge due to the damage to the downstream reaches or other unavoidable reasons, NIA MAGAT may adjust the discharge regardless of the pre-release plan.

(g) Resumption of Discharging

When it is considered suitable and necessary to resume the discharging after the suspension, NIA MAGAT shall issue again dam discharge warning and restart the discharging for the pre-release after modifying the prerelease plan.

4.2.2. Spillway Operation

In compliance with the Presidential directive of December 2006, the operation of the spillway shall be carried out by NIA MAGAT based on the instructions of PAGASA. The spillway gates of Magat shall be opened for pre-release based on the existing procedure stipulated in this Manual. Also, the volume or rate of water to be released shall be made such that there will be no abrupt increase in the water level downstream of the dam.

a. Operation Criteria

There are three criteria which constrain the operation of the Magat Reservoir for flood mitigation:

(2) The rate of spill from the Magat Reservoir must be limited to the maximum non-flooding level downstream from the dam while the reservoir level is below Elevation 193.00

(3) The reservoir drawdown must be limited at any time to a level for which the volume available for flood storage is equal to the flood volume forecasted with a suitable allowance for forecasting errors.
(4) When the reservoir level is at Elevation 193.00, all flows coming into the reservoir must be passed through the hydroelectric plant or spillway or both. That is, the level of the reservoir must be limited as closely as possible to Elevation 193.00 during the passage of the flood.

The RESERVOIR LEVEL CRITERION is necessary to protect the safety of the dam, to prevent loss of lives, minimize damage to crops and property, ensure that the reservoir will refill to its operation rule level and maximize power generation. The safety of the dam is the foremost criterion and MUST NOT BE VIOLATED UNDER ANY CIRCUMSTANCES.

IT IS EMPHASIZED THAT THERE IS NO PROVISION FOR THE STORAGE OF FLOOD WATER IN THE MAGAT RESERVOIR unless the reservoir is below the full supply level (Elevation 193.00) when the flood arrives. When a flood arrives with the reservoir at Elevation 193.00 that flood is passed through the spillway in its entirety and without interruption. As far as conditions downstream from the dam are concerned, the dam has no effect on the flood which arrives with the reservoir at the full level. There is no more nor any less downstream flood damage due to the dam.

b. Principles of Flood Passing Operations

The operating principles for flood spillway releases are as follows:

(1) There is no flood storage space allotted in the Magat Reservoir except that provided by operating the reservoir to keep it at levels below full supply level during the months of June, July, August, September, October and November (see Figure 4.1).

(2) The storage between Elevation 193.00 meters and the top of the Dam at Elevation 200.00 meters is provided to accommodate the rise in water level that will take place during the passage of the design flood even with all spillway gates open. DO NOT STORE WATER ABOVE ELEVATION 193.00 UNDER ANY CIRCUMSTANCE.

(3) WITH THE RESERVOIR LEVEL AT THE FULL SUPPLY LEVEL OF 193.00 METERS, EXCESS FLOOD WATER MUST BE PASSED STRAIGHT THROUGH THE SPILLWAY. Water levels and conditions downstream of the dam are essentially the same for the stage of the flood as they would have been had there been no dam at Magat.

(4) Releases through the spillway should, if possible, be made to match excess inflows by opening the gates step by step in the required sequence to maintain the reservoir level at elevation 193.00 until all spillway gates are fully open.
(5) Spillway gates are closed step by step in the required sequence when the reservoir level reaches Elevation 193.00.

(6) All gate openings or closings are authorized by the PAGASA in close coordination with the MARIIS OM, the DRD Manager and the Head of the Electrical-Mechanical Section.

c. Opening of Spillway Gates

**FLOOD RELEASES THROUGH THE SPILLWAY SHALL COMMENCE IN ACORDANCE WITH THE PRE-RELEASE PLAN**

During the pre-release and within the passage of the flood, the spillway gates must be opened in the sequences and steps given in table 4.1. The reservoir must be continuously observed and the next opening step shall not be made unless the reservoir level still tends to rise. HOWEVER, THE NEXT STEP MUST BE TAKEN IMMEDIATELY IF THE RESERVOIR IS STILL RISING.

The orifice spillway gates (Gate 8 and Gate 9) shall be operated together (simultaneously) but do not enter the gate opening sequence until the spillway discharges exceed 8540 cubic meters per second. This sequence has been determined as that which minimizes erosion in the plunge pool.

**THIS OPENING SEQUENCE SHALL BE FOLLOWED WITHOUT EXCEPTION** unless a particular gate is inoperable in which case it is dropped from the sequence, or when particular spillway chute is undergoing maintenance work, in which case the gates belonging to that chute shall be dropped from the sequence. IF ALL GATES ARE OPENED FULLY EXCEPT THOSE BELONGING TO A CHUTE UNDER REPAIR, AND THE RESERVOIR CONTINUES TO RISE THEN THAT CHUTE SHALL BE PUT INTO SERVICE NO MATTER WHAT WORK IS OR WAS GOING ON IN THE CHUTE. The gates in that chute shall be opened step by step. Every possible effort must be made to get an inoperable gate back into service.
### TABLE 4.1

MAGAT SPILLWAY GATE OPENING STEPS

<table>
<thead>
<tr>
<th>STEP</th>
<th>GATE NUMBER</th>
<th>OPEN GATE TO METERS</th>
<th>TOTAL DISCHARGE FOR RESERVOIR AT ELEVATION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>193.00</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>1</td>
<td>200</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>2</td>
<td>440</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>1</td>
<td>640</td>
</tr>
<tr>
<td>4</td>
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<td>2</td>
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<td>1</td>
<td>1080</td>
</tr>
<tr>
<td>6</td>
<td>5</td>
<td>2</td>
<td>1320</td>
</tr>
<tr>
<td>7</td>
<td>6</td>
<td>1</td>
<td>1520</td>
</tr>
<tr>
<td>8</td>
<td>6</td>
<td>2</td>
<td>1760</td>
</tr>
<tr>
<td>9</td>
<td>7</td>
<td>1</td>
<td>1960</td>
</tr>
<tr>
<td>10</td>
<td>7</td>
<td>2</td>
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</tr>
<tr>
<td>11</td>
<td>1</td>
<td>1</td>
<td>2400</td>
</tr>
<tr>
<td>12</td>
<td>1</td>
<td>2</td>
<td>2640</td>
</tr>
<tr>
<td>13</td>
<td>2</td>
<td>1</td>
<td>2840</td>
</tr>
<tr>
<td>14</td>
<td>2</td>
<td>2</td>
<td>3080</td>
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<tr>
<td>15</td>
<td>4</td>
<td>4</td>
<td>3520</td>
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<tr>
<td>16</td>
<td>3</td>
<td>4</td>
<td>3960</td>
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<tr>
<td>17</td>
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</tr>
<tr>
<td>28</td>
<td>2</td>
<td>6</td>
<td>8540</td>
</tr>
<tr>
<td>29</td>
<td>Orifice gates (8,9)</td>
<td>3</td>
<td>9220</td>
</tr>
<tr>
<td></td>
<td>Opened (8,9)</td>
<td>6</td>
<td>9880</td>
</tr>
<tr>
<td>30</td>
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</tr>
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<td>8</td>
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</tr>
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<td>8</td>
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<td>35</td>
<td>7</td>
<td>8</td>
<td>12160</td>
</tr>
<tr>
<td>36</td>
<td>1</td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>
The discharges for the ogee and orifice spillway gates fully open for reservoir levels other than Elevation 193.00 are given in Figure 4.4. The discharge rating curves for one ogee spillway gate alone is given in Figure 4.5 and for two orifice spillway gates operating alone, in Figure 4.6.

Flow through a spillway gate is affected by flow through neighboring gates. The flow through the seven ogee gates open together is approximately two percent less than seven times the discharge through one gate open alone.

d. Closing Spillway Gates

The following closure procedure shall be strictly followed:

1. When the reservoir starts to fall, the spillway gates shall be closed in the reverse sequence to that used for opening the gates. First, Gates 8 and 9 are partially closed simultaneously followed by Gates 2, 1, 7, 5, 3 and 4 in sequence.
2. For floods smaller than 8,540 cubic meters per second, Orifice Gates 8 and 9 are not opened.

3. The gates shall be closed in two-meter steps as shown in Table 4.1 unless all gates are fully open. They shall be closed as quickly as is necessary to prevent the reservoir from dropping below Elevation 193.00.

4. They shall continue to be closed while the reservoir level continues to fall. If the reservoir level stops falling, then the gate closing sequence shall be halted until the reservoir starts to fall again when the gate closing shall be started again.

5. If the reservoir should start to rise again, the gate opening procedures shall be started from the step in the sequence where closing was halted.

6. For floods in which all gates are fully open, the gates shall remain fully open until the reservoir level drops to Elevation 193.00. Then the gate closing sequence shall be followed until all gates are closed. When the reservoir level reaches Elevation 193.00, again the gate opening sequence shall be employed to match inflows and outflows from the reservoir and to hold the level as closely as possible to Elevation 193.00.

7. At the end of the flood, final adjustment to bring the reservoir to Elevation 193.00 shall be made by operation of Gate 7 in conjunction with clearing debris from the reservoir. (See Section 4.3.1 DEBRIS IN RESERVOIR).

The object of the closing operation is to continue to pass the flood through the spillway and to return the reservoir level to Elevation 193.00. It is always possible that a second flood will arrive right behind or even overlapping the first flood. It is therefore very important that the reservoir level of 193.00 meters be re-established as soon as possible.

DO NOT CLOSE SPILLWAY GATES UNLESS THE RESERVOIR IS FALLING. ALL SPILLWAY GATES SHALL BE CLOSED WHEN THE RESERVOIR LEVEL IS STABLE AT ELEVATION 193.00 METERS AND ALL SUBSEQUENT RELEASES TO RETURN THE RESERVOIR TO RULE CURVE ELEVATION SHALL ONLY BE MADE THROUGH THE POWER PLANTS.

4.2.3 EMERGENCY RELEASES

Following an event such as a major earthquake, it may become necessary to drawdown the reservoir to inspect the structures. EMERGENCY RELEASES ARE MADE ONLY WHEN DIRECTED BY THE OPERATIONS MANAGER UPON PROPERLY ADVISED BY THE DRD MANAGER on the rate and extent of such releases. For more detailed instructions regarding emergency releases, refer to Section 7.5.
4.2.4 DEBRIS IN RESERVOIR

From time to time floating debris accumulates near the power intakes. It is important that these debris be removed as quickly as possible by the Civil Works Section before it sinks in the vicinity of the trash racks of the power intakes. If such debris can not be cleared with boats or by other standard operations when the flow being passed over the spillway is about 3000 cubic meters per second, the following debris clearing operation shall be carried out:

- Close all gates except Gate 7
- Fully Open Gate 7
- When the debris has been passed or when the reservoir falls to elevation 193.00, whichever occurs first, close Gate 7.
- If after clearing the debris, the reservoir is above Elevation 193.00, determine the flow passing through Gate 7 from Figure 4.5 and open the required gates to the position shown in Table 4.1 for that flow.
- Continue with gate closing as in Section 4.2.2.d

Any timber remaining in the headworks area after all spillway gates have been closed shall be removed by any safe means. DO NOT ATTEMPT THIS WORK UNTIL IT IS CERTAIN THAT SPILLWAY GATES WILL NOT BE OPERATED.
CHAPTER 5

OPERATION AND MAINTENANCE OF EQUIPMENT

5.1 SPILLWAY

5.1.1 Ogee Spillway Radial Gates

These gates are provided to release flood water from the reservoir. There are seven ogee spillway gates numbered 1 to 7 from the north end of the spillway. The crest of the ogee is at Elevation 174.00. Each gate is 16.50 meters wide and 20.0 meters high and can be operated either partially or fully open for long periods of time at all reservoir levels.

The gate consists of a curved skin plate and a system of girders which transmit the water loads to the radial arms and thence to the steel trunnion beam which spans between piers. The trunnion beam is anchored to the upstream end of the piers by steel cables which are embedded in the piers. The gate is raised or lowered by an electrically driven chain hoist mounted at the top of the piers. A synchronizing shaft transmits power to the chain on the other side of the gate. The gates open and close at a speed of 0.50 meter per minute. The hoist automatically stops when the gate reaches the fully open or fully closed positions. At the fully open position, the lip of the gate is at Elevation 193.50 and the gate opening normal to the ogee slope is 20.445 meters. There is a position indicator at each to monitor the position of the gate through its full range of travel. Gate positions are also relayed to the spillway gatehouse. The operation of each gate may be controlled from either the push button panel mounted next to the gate hoist or remotely from the central control board in the spillway gate house.

The sill and side seals are elastomeric with the side seals having fluoro-carbon insets to reduce friction. All seals are adjustable.

Access to the hoist is from the spillway bridge while access to the gates is from the trunnion beams. Access to the beams is from the walkways and platforms at the orifice spillway or ladder at the downstream slope of Spillway Bay Pier 1. Stop logs are provided to be installed in slots upstream of the gate when servicing or maintenance is required.

5.1.2 Orifice Spillway Radial Gates

The Orifice Spillway consists of two bays each equipped with a 6.00 meter wide by 12.50 meter high radial gate. The gates are numbered 8 and 9. The bottom of the orifice opening is at Elevation 147.00. The gates are operated by oscillating electro-hydraulic cylinder hoist mounted on platforms between the piers. Stop logs are provided to be installed in slots upstream of the gates when servicing or maintenance is required.
The Orifice Spillway is provided to:

- Enable the reservoir to be drawn down to Elevation 147.00 meters in cases of extreme emergency
- Assist in passing large flood through the spillway
- Release irrigation water in the event of the power station being completely closed down with the reservoir level being lower than Elevation 174.00 meters.

The sequence and extent of gate opening for passing large flood is detailed in section 4.2.3 – FLOOD SPILLWAY RELEASES. When operation for reservoir drawdown is required in case of extreme emergency, both orifice spillway gates are opened fully for the time required to draw the reservoir down to the desired elevation.

Each gate is operated by an oscillating single-acting hydraulic actuator controlled locally. The actuator provides the force required to open the gate under all reservoir levels and acts as a cushion when the gate is closing under its own weight. The observed deflection of the gate lifting stem is due to the bending moment produced by the stem’s dead weight. The manufacture’s calculations take this bending moment into account for calculating the required stem diameter.

The gates open and close at a speed of 0.50 meter per minute for the last 200 millimeters of travel during the closing stroke when the speed is automatically reduced to 0.10 meter per minute. In an emergency, the gate can be raised manually using a hand pump, or lowered by use of a HAND-EMERGENCY DEVICE provided on the solenoid operated control valve. The gates can be operated either partially or fully open for long periods of time at all reservoir levels.

Each gate consists of a curved skin plate and a system of girders which transmit the water loads to the radial arms and thence to the concrete trunnion beam which spans between piers. The trunnion pin is solid steel and is hard chrome-plated. Each gate has three guide shoes on each side. The lintel seal and side seals are of the single stem bulb type faced with a bonded Teflon insert. A rectangular rubber seal is provided at the sill. All seals are adjustable to enable leakage to be rectified. An anti-jet seal is provided at the lintel to prevent water from jetting between the gate and the lintel when the gate is open.

Access to the hoist equipment platform at Elevation 188.00 meters is via stairway constructed in Pier 9. A gallery through Pier 9 allows access between equipment platforms. There is also a ladder from the platform in Bay 9 to the top of Pier 9 at Elevation 200.00. There is a system of ladders and platforms which provide access to the tops of the gate trunnion beams.
5.1.3 OPERATION

Detailed Instructions for the operation of the spillway gates are given in Volume 5 – Operating and Maintenance Instructions - Ogee Spillway Gates and Stop Logs and Volume 8 – Operations and Maintenance Instructions – Orifice Spillway Gates and Stop Logs.

a. Ogee Spillway Radial Gate Operating Instructions

(1) Normal Local Operation Using Normal power Supply or power Supply From the Standby Stationary Diesel-Generator Unit

1.1 Check the distribution board in the spillway substation. Be sure the circuit breaker of the gate to be operated is “ON”.
1.2 Proceed to local control of gate. Check sprockets, chain and open gears. These should be free from obstructions.
1.3 Check main circuit breaker MCB-1 and control circuit breaker MCB-2. Be sure the breakers are “ON” and voltmeter reading is within the allowable range from 456 to 504 volts.
1.4 Press push button “Lamp Test” and note fault or busted bulbs.
1.5 Turn snap switch to “LOCAL”
1.6 Switch on control circuit.
1.7 To raise gate, press “RAISE” button. Gate position can be read from the position indicator.
1.8 To lower gate, press “LOWER” button.
1.9 To stop gate at any position other than fully closed or fully opened, press “STOP” button. Gate automatically stops when reaching fully opened or fully closed position. Take note of the starting current of motor. Also observe chain actions at both sides of gate while operating.
1.10 After operation, turn off snap switch for control circuit.

(2) Normal Local Operation Using the Portable Emergency Power Unit

NOTE:

THIS OPERATION SHALL BE DONE ONLY WHEN THERE IS NO POWER SUPPLY FROM THE NORMAL power SOURCE AND FROM THE STANDBY STATIONARY DIESEL-GENERATOR UNIT.

2.1 For safety reasons, manually SWITCH OFF the Main Circuit Breaker in the Spillway Substation.
2.2 Also at the Spillway Substation, manually SWITCH OFF the Main Circuit Breaker of the Radial Gate Control Panel to be operated.

2.3 Bring the Portable Diesel-Generator Unit near the local control panel of the radial gate to be operated.

2.4 At the Local Control Panel of the Radial Gate to be operated, SWITCH OFF main circuit breaker MCB-1.

2.5 Connect the Power Plug from the Portable Generator Output line to the Receptacle in the Radial Gate Control Panel.

2.6 Check the radial gate's sprockets, chains, open gears for any obstruction.

2.7 Start the Portable Diesel-Generator unit and adjust voltage to the operating voltage.

2.8 SWITCH ON the breaker of the Portable Diesel-Generator Unit.

2.9 Follow steps 1.4 through 1.10 above.

2.10 SWITCH OFF the breaker of the Portable Diesel-Generator Unit then STOP the engine.

2.11 Disconnect the Generator output line from the Receptacle in the gate control panel.

(3) REMOTE CONTROL OPERATION USING NORMAL POWER SUPPLY OR POWER SUPPLY FROM THE STANDBY STATIONARY DIESEL-GENERATOR UNIT

3.1 Check circuit breaker of gate to be operated in the spillway substation. Be sure it is ON.

3.2 Turn snap switch in the local control cabinet to "REMOTE".

3.3 In the Remote control Panel, turn selector switch to "REMOTE", then switch ON the circuit breaker for control circuit.

3.4 To raise gate, press "RAISE" button.

3.5 To stop the gate at any position, press "STOP" button. Gate automatically stops when reaching fully closed or fully opened position.

3.6 To lower gate, press "LOWER" button.

3.7 After operation, turn selector switch to local and turn off circuit breaker for control circuit.

b. ORIFICE SPILLWAY RADIAL DATE OPERATING INSTRUCTIONS

1. NORMAL OPERATION

1.1 Check circuit breaker for Orifice Spillway Gates at the spillway substation. Be sure it is ON.

1.2 Check hydraulic oil level in the hydraulic power unit. Be sure oil level is normal.
1.3 Turn on switch Q1 in the local control cabinet. At this point indicating lamps H1-control supply on, H2-DC supply on, H3-AC supply on should be lighted.

1.4 Check voltmeter PIN reading. Be sure voltage reading is between 456 to 504 volts.

1.5 Check phase voltage by turning phase selector switch S1. Be sure each reading is within the allowable range.

1.6 Check indicating lamps. Note any fault or busted bulbs.

1.7 Check hydraulic oil temperature. When ambient temperature is cold, warm oil for about 5 minutes by pressing push button S6-Pump Start. Stop pump by pressing push button switch SS-pump stop.

1.8 To raise gate, press push button S7- GATE RAISE. As soon as the gate is lifted, GATE SHUT bulb extinguishes and “GATE IN TRANSIT” lamp is lighted. Gate position can be read from position indicator P3N.

1.9 To stop gate at any position other than fully opened or fully closed, press push button S8-“STOP”. Gate stops automatically when reaching fully opened or fully closed positions.

1.10 To lower gate, press push button S9-Lower.

1.11 After operation, turn off main switch Q1.

(2) MANUAL OPERATION

(a) RAISING
Check ball cocks. The following valves should be open: 15,16.1,10.1,18; closed: 10.2.
Raise gate by manually operating hand pump 13.

(b) LOWERING
Remove housing of valves at hydraulic cylinder upper end.
Press hand emergency device of solenoid operated valve 32.

c. STANDBY STATIONARY POWER GENERATOR UNIT OPERATING INSTRUCTIONS

(1) PRELIMINARY CHECK

1.1 Check engine oil level. Be sure it is normal.
1.2 Check fuel stock. Be sure there is enough fuel.
1.3 Open valves for fuel supply and return lines
1.4 Check cooling water. Be sure the radiator is filled up to the pressure cap level.
1.5 Check batteries.
(2) **STARTING THE DIESEL-GENERATOR UNIT**

2.1 Switch ON toggle switch for panel metering
2.2 Insert ignition key and start the engine.
2.3 Run engine at idle speed for 3-5 minutes.
2.4 Slowly adjust engine speed and observe the frequency and voltage increase. Readings should be 60 hertz, 460 volts.
   Turn the voltage adjusting knob to adjust voltage.
2.5 Get clearance from the substation operator before switching ON the generator breaker.

(3) **STOPPING THE DIESEL-GENERATOR UNIT**

3.1 Get clearance from the substation operator before disconnecting the generator breaker.
3.2 After switching OFF the generator breaker, reduce the engine speed until it reaches idle RPM
3.3 Switch OFF ignition and retrieve the key.

5.1.4 **PERSONNEL**

Personnel operating the Spillway Gates shall work as a team of four on a shift throughout the flood season. The four operators on shift shall be on duty at the headworks structure with specific assignment as follows:

- One Team Leader
- One Gate Operator
- One Spillway/Power Intake Substation operator
- One Standby Power Unit operator.

When it is known that a storm is approaching or when it is predicted that the reservoir will rise above elevation 193.00, all available off-duty personnel shall be called to the spillway gatehouse by the Head of the Electrical-Mechanical Section to act as a standby team in case of emergency. The Head of the Electrical-Mechanical Section shall immediately inform the DRD Manager when both teams are in position.

One reservoir elevation Observer per shift from the Instrumentation Section shall be stationed at the Spillway headworks. He shall continuously observe and record the reservoir level then relay the information to the Operations Center at the DRD office. Instructions for gate operations shall emanate from the Operations Center and relayed directly to the Team Leader of Spillway Gate Operators.
5.1.4 COMMUNICATION

Telephone communication is provided between the spillway gate house and the MHEPP. In addition, the gate operators and observer shall be equipped with one VHF Radio Transceiver based at the gate house, one VHF Portable handheld transceiver each for the operators and observer, one Cellular Phone each for the operators and observer.

5.1.5 EMERGENCY POWER

If the main power supply from the Magat Hydroelectric Plant should fail, then the stationary standby diesel-generator unit located at the Left Interface must be started to provide power to the gate hoists. If this standby generator fails, then the portable diesel-generator unit kept at the generator house at the Left Interface must be brought to the Spillway bridge for operation.

5.1.6 MAINTENANCE

a. OGEE SPILLWAY GATES
   - (Refer to Volume 5 - Operating and Maintenance Instructions - Ogee Spillway Gates and Stop Logs)

   Certain maintenance work can be carried out with the gate closed. However, any maintenance work on the upstream face, the seals, or the unloaded trunnion, can only be carried out after the stop logs have been installed and the spillway bay dewatered. The oggee spillway stop logs are in six sections, each section being stored in the top of a stop log slot in six bays of the oggee spillway.

   (1) Stop logs installation - (Refer to Volume 5- Operating and Maintenance Instructions - Ogee Spillway Gates and Stop Logs)

   To install stop logs in a particular spillway bay the following steps are necessary:
   - Close the spillway gates
   - Remove the stop log shaft covers in all bays.
   - Prepare grappling beam and remove the stop log section that is stored in the bay and place it in the spillway bay that has no stop log section stored in it.
   - Install the six stop log sections in their correct order. The sections are numbered 1 through 6. Number 1 stop log is the bottom stop log.
   - Crack open the spillway gate to drain the space between gate and stop log

   The stop log sections are handled by the oggee spillway lifting beam and the headworks gantry crane. (See Section 5.3). The location of each stop log’s center of gravity varies from stop log to stop log. The guide rollers of the lifting beam must be repositioned slightly with each stop log in order to place
them in vertical alignment, with the center of gravity. The lifting beam is stored in the stop log slot that is not occupied by a stop log section. The stop logs seal on the downstream side of the slot.

Each stop log section is provided with a landing sensing probe which prevents the automatic dis-engagement of the lifting beam hooks unless the section is correctly seated in position.

The lifting beam is designed to lift the heaviest stop log. Attempts to handle more than one section at a time must not be made. Each section must be installed and removed from its position in the stop log slot individually.

(3) Stop log removal — (refer to Volume 5 – Operating and Maintenance Instructions – Ogee Spillway Gates and Stop Logs)

Each section is provided with a by-pass valve. These valves are operated by a hand wheel located on the top of each stop log section and allow water to enter the space between the stop log and gate so that the pressure on the stop logs can be equalized to allow their removal.

To remove a stop log from a slot the following steps are necessary:

- Close the spillway gate
- Remove stop log sections as may be necessary to enable the highest by-pass valve that is also below water level to be operated.
- Open the highest by-pass valve that is below reservoir level and fill the section between stop logs and gate with water.
- Remove the remaining stop log sections and place them in the stoplog slots of adjacent bays.
- Place the lifting beam in the vacant slot

(b) ORIFICE SPILLWAY GATES

(Refer to Volume 8 – Operating and Maintenance Instructions – Orifice spillway Gates and Stop Logs)

Certain maintenance work can be carried out with the gate closed. However, any maintenance work on the upstream face, the seals, the hydraulic hoist, or the unloaded trunnion, can only be carried out after the stop logs have been installed and the spillway dewatered.

Four separate sections form one stop log set which will close one orifice spillway bay. The two lower sections are stored in the stop log slots of Bays 8 and 9 and are dogged in position. The two remaining sections are stored in the slots cast in the concrete breastwall downstream of the stop log slots.

(1) Stop Log Installation
The stop log sections are transported and operated by the headworks gantry crane which would be equipped with the orifice spillway lifting beam.

The stop log sections can only be installed or removed under balanced pressure, which means that the corresponding orifice radial gate must be closed at such times.

(2) Stop Log Removal

The stop logs seal on the downstream side of the slot. The top stop log section is provided with 2/250 millimeters diameter by-pass valves. These valves are operated by the lifting beam and allow water to enter the space between stop logs and gate so that the pressure on the stop logs can be equalized to allow their removal.

Each stop logs section is provided with a lending sensing probe which prevents automatic disengagement of the lifting beam hooks unless the section is correctly seated in position.

The lifting beam is designed to handle the heaviest stop log. Attempts must not be made to handle more than 1 section at a time. Each section must be installed in and removed from its position in the stop log slots individually. The sections must not be joined together in any way to attempt raising or lowering as a set.

c. ROUTINE MAINTENANCE

Detailed instructions for normal maintenance are given in Volume 5 and Volume 8 of this Manual. In addition, once a month, the ogee spillway gates shall be inspected and then trial operated one at a time. Each gate shall be crack opened individually by 50 mm and then closed immediately. There is no need to install the ogee stop logs for these trial operations.

Once each five years when the reservoir is at low level and is starting to re-fill, the orifice spillway gates shall be inspected, serviced and trial operated in the dry. The stop logs must be installed before operating either gate.

The two emergency power diesel-electric generator units located in the generator house are to be maintained in top class operating condition. Each shall be started and test operated and loaded at least once in each month. Each week, the engine shall be started and warmed up. An adequate fuel supply for long hours of operation shall be stored in the respective fuel tanks.
d. INSPECTION AFTER EARTHQUAKE

Following any significant earthquake, nominally an earthquake generating a site acceleration of 0.05 g or greater, all spillway gates shall be carefully inspected and trial operated in the dry through the full range of travel. The stop logs must be installed before operating any gate.

c. SCHEDULES

(See Section 5.8 and Volume 5. Operating and Maintenance Instruction Ogee Spillway Gates and Stop Logs and Volume 8 – Operating and Maintenance Instructions Orifice Spillway Gates and Stop Logs.)

5.2 THE POWER INTAKES

The closure gates in the power intakes are operated by NIA, but the power plant operator can close the gates via remote control in case of emergencies. Maintenance of intake equipment shall be done at every opportunity simultaneously as the power plant operator maintains the hydroelectric plant equipment. NIA shall advise the power plant operator of any necessary maintenance work and shall request the power plant operator to shut down the affected unit if necessary.

There are six openings through the power intake structure which are steel-lined downstream of the closure gate slots. Four of these openings (numbered 1 to 4 from the south end of the intake structure) are connected to penstocks which in turn are connected to turbines in the powerhouse. The remaining two openings (5 and 6) have steel bulkheads welded to the liners at their downstream ends. At some future date, turbines 5 and 6 may be installed in the powerhouse and penstocks 5 and 6 constructed.

All openings are equipped with trash racks, closure gates and hoist. A bulkhead gate is supplied to allow any one closure gate to be serviced.

5.2.1 TRASH RACKS
- (Refer to Volume 6 – Operating and Maintenance Instructions – Intake Gates Bulkhead Trash racks)

Each penstocks intake is divided into two sections by a vertical central pier. The two resultant openings are protected by two sets of trash racks, each set being 5.30 meters wide and 12.40 meters high. Each set is comprised of 4 sections each about 3.00 meters high. The trash racks are constructed with heavy horizontal steel plates acting as beams. The plates in the top and bottom sections are angled to help streamline the water flow through the racks. The plate beams support the trash rack bars which are spaced at
116 millimeters on centers. The clear space between bars and beams is approximately 1 meter x 100 millimeters.

The four rack sections are connected together into one unit for installation and removal by the lifting beam. Each section has a trash tray at its lower end. There is no provision for cleaning the racks in place and when cleaning is requested by the Power Plant Operator, the complete rack unit must be lifted to the top of the intake structure, disassembled, cleaned, re-assembled, and re-installed. The turbine must be shut down and the closure gate closed, and bulkhead gate installed before a trash rack is removed from its opening. The trash racks are handled by the rack lifting beam and the headworks gantry crane (see Section 5.3).

5.2.2 CLOSURE GATE

(Refer to Volume 6 - Operating and Maintenance Instructions - Intake Gates Bulkhead Trashrack)

Each closure gate closes an opening 5.00 meters wide x 5.50 meters high. The gate was fabricated from heavy steel plates and beams in two sections for ease of transport. The two sections have been rigidly bolted together to form one piece gate. The gate has an upstream skin plate and seals or its upstream side. The side seals are single stem bulb type, while the sill seal is a rectangular rubber seal. The gate has six heavy 700 millimeters diameter bearing rollers and two side guide rollers at each side.

The gate hoist is a hydraulic actuator which is suspended from a steel beam 5.50 meters below the deck of the intake structure.

The actuator is connected to the gate by a series of steel lifting rods. At Elevation 181.00 there is a system of dogging beams to allow the closure gate to be removed from the slot by dogging and removing one lifting rod at a time. It is intended that the closure gate be serviced and repaired in the enlarged shaft above Elevation 181.00. Devices have been provided in the enlarged shaft to support the top of the gate following the removal of the hydraulic actuator if this becomes necessary. The lifting rod dogging beams are portable so that the one set can be used in any closure gate shaft.

The oil tank, pump and motor and all other devices and controls required for the operation of the hydraulic actuator are located in the equipment room at Elevation 196.00 meters downstream of the gate slot.

There is a sensing device installed just above the penstock, to sense an increase in velocity that would result from a penstock bursting. In such event the closure gate would automatically close.

5.2.3 INSTRUMENTS

The following instruments are located in the equipment room.

- Closure gate position indicator
5.2.4 OPERATION

WHENEVER POSSIBLE, ALL OPERATIONS SHOULD BE PERFORMED WITH CONCURRENCE BY THE POWER PLANT OPERATOR.

Detailed Instructions for the operation of the intake closure gates are given in Volume 6 – Operating and Maintenance Instructions – Intake Gates Bulkhead Trash racks.

All gate operations are made from the gate equipment room in the top of the intake structure except that the “Emergency Close” operation may also be made from the Magat Hydroelectric Plant Control room.

The closure gate will normally be either fully open or fully closed. The closure gate will normally be closed under balanced pressure conditions (no flow) but it is capable of gravity closure against the maximum water flow due to the penstock bursting. The hoist is capable of lifting the closed gate against the maximum upstream reservoir pressure, with the penstock dewatered, to fill the penstock.

The actuator is single acting in the gate raise direction but is capable of being driven UNLOADED in the gate close direction at reduced operating pressure. Operating speeds are:

- Raising against maximum upstream water pressure with penstock dewatered – 0.15 meter per minute.
- Raising under balanced conditions – 1.00 meter per minute.
- Lowering under balanced conditions – 1.00 meter per minute.
- Emergency lowering under flow – 12.00 meters per minute.
- Final 0.15 meter of gate closure stroke both normal and emergency lowering – 0.20 m/min.

The change of speed is automatic.
Intake 1 should not be used when the reservoir level is below Elevation 172.00 meters because of the possibility of vortex formation.
Any other intakes can be used.

a. FILLING THE PENSTOCK

The closure gate is raised 250 millimeters by pressing the “Gate Crack pushbutton. The penstock is allowed to fill with displaced air being released through the gate shaft downstream of the closure gate. The gate can be raised fully after the penstock is full. The turbine in the power plant can be put into operation.

b. INDICATION AT POWERHOUSE
The following conditions are indicated in the Magat Hydroelectric Plant control room.

- Gate shut
- Gate open
- Gate in transit
- Penstock primed (full)
- Gate restore inoperative

**POWER INTAKE CLOSURE GATE OPERATING INSTRUCTIONS**

1. **PRELIMINARY CHECK**
   - Check circuit breaker of gate to be operated in the power Intake Substation. Be sure it is on.
   - Check hydraulic oil level in tank. Be sure it is normal.
   - Check stop valves. Valves 34 and 38 should be open; valves 35, 36 and 37 should be closed.

2. **CRACKING OPERATION**
   Gate cracking operation is performed when penstock is empty or not fully filled with water. If penstock is full and water condition is balanced as indicated in the control panel, raising operation can be done directly. This can be confirmed by checking the gate shaft.

   - After doing preliminary checks, set selector switches in the local control cabinet as follows:

     | COS-1 | COS-2 | COS-3 |
     |-------|-------|-------|
     | LOCAL | NORMAL | PUMP NO.2 (CRACK) |

   - Switch on circuit breakers MCB-1, MCB-2 and MCB-3.
   - Check voltmeter reading. Be sure AC voltage is between 456 to 504 and DC voltage is between 118 to 132.
   - Press push button switch “CRACK”. Buzzer sounds and gate starts to travel.
   - Switch off buzzer by pressing button “BUZZER STOP”.
   - Gate automatically stops when it is 25 centimeters off sill.
   - When indicator “PENSTOCK PRIMED” is lighted, observe condition at gate shaft first before proceeding with the raising operation. Be sure there is no more noise from the shaft and water level in the shaft approximates the water level in the impoundment.
(3) **RAISING OPERATION**
- Set selector switch COS-3 to pump 1. Leave other settings done in crack operation as is.
- Press "RAISE" button.

Gate is designed to operate at fully opened position. Gate automatically stops when fully opened or fully closed. However, should there be a need to stop the gate at any position, press push button PB4 “Gate Stop”.

- Always set selector switches COS-1 to “Remote”, COS-2 to “Normal”, COS-3 to “Pump No. 1” after fully opening the gate. “GATE RESTORE” will not function if the switches are not in these positions.

(4) **NORMAL LOWERING OPERATION**
- Selector switch settings are same as in 3-Raising Operation.
- To lower gate, press “LOWER” button.

(5) **EMERGENCY CLOSING OPERATION**
- Emergency closing can be done by remote control from the powerhouse by pressing the emergency close button.

- Emergency closing can also be done locally in two ways:
  1) Set selector switch COS-1 to “LOCAL” then press ‘EMERGENCY LOWER” button, or
  2) By releasing lever or counterweights for “OVER VELOCITY DEVICE”. Lever is situated far back of the position indicator.

5.2.5 **MAINTENANCE**

**MAINTENANCE SHOULD BE PERFORMED ONLY WITH THE CONCURRENCE OF THE POWER PLANT OPERATOR.**

Maintenance of the equipment in the equipment room can be done at any time. Work on the closure gate and hoist can only be done after installing the intake bulkhead gate and dewatering the intake waterway.

a. **BULKHEAD GATE**

The Bulkhead Gate was fabricated in two sections in the shop then were bolted together at the site. It is constructed from heavy beams and plates. The gate is of the sliding type with downstream skin plate and seals. It has lifting brackets at the top which allow it to be lifted or lowered by the headworks gantry crane and grappling beam. The bulkhead gate is stored on
dogging beams at the top of Bulkhead Shaft # 6. The gate has single stem bulb seals at each side, a double stem seal at the lintel, and a rectangular rubber seal at the sill.

The bulkhead is fitted with a by-pass valve to allow the space between the bulkhead and closure gate to be filled with water and allow the pressure across the bulkhead to be equalized before raising the bulkhead. The valve is operated by the action of the lifting beam. A pipe between the two gate slots allows air to be drawn in or to be exhausted.

A device called “operating ramp” is installed on the gate guides at Elevation 156.26 which deactivates the lifting beam safety device. The safety device prevents the automatic disengagement of the grappling hooks before the gate is correctly seated in position. The lifting beam must be lowered past the device on the gate guides before the hooks can be disengaged.

Guide rollers are provided on the top and at the bottom of each side of the gate.

b. DEWATERING

The following steps need to be taken:
(1) Shut down the powerhouse turbine
(2) Close the closure gate
(3) Dewater the penstock downstream of the closure gate by opening the turbine wicket gates
(4) Install the bulkhead gate if work is required to be done on the closure gate or hoist.
(5) Crack open the closure gate and drain the water from the space between the gates (if step 4 is taken). Air is supplied through the vent pipe.

c. LIFTING OF CLOSURE GATE TO THE MAINTENANCE CHAMBER

This is explained step by step in detail in Volume 6 – Operating and Maintenance Instructions – Intake Gates Bulkhead Trashracks

d. REFILLING OF THE PENSTOCK

Assuming that the bulkhead gate has been installed, the following steps shall be taken.
(1) Re-establish the closure gate in its correct operating position. Close the closure gate.
(2) With the headworks gantry crane and the grappling beam, operate the by-pass valve in the bulkhead gate to fill the space between gates with water and to balance the pressure on each side of the bulkhead gate.
(3) Raise the bulkhead gate and store (dog) it at the top of the Bulkhead Shaft # 6.
(4) Check that the turbine wicket gates are closed.
(5) Crack the closure gate and allow the penstock to fill. The "Penstock Full" indicator will operate when the penstock is full.
(6) Raise the closure gate fully.

e. ROUTINE MAINTENANCE

Detailed instructions for normal maintenance are given in Volume 6- Operating and Maintenance Instructions- Intake Gates Bulkhead Trashrack. In addition, once each three months, or at any maintenance opportunity the Intake Closure Gates 1, 2, 3, and 4 and their hoist shall all be inspected and then trial operated one at a time. Intake Gates 5 and 6 will likewise be operated once in every three months to prevent corrosion in the hydraulic lines and actuator. After shutting down the turbine, each gate in turn shall be operated through a dull cycle of FULLY OPEN-FULLY CLOSED-FULLY OPEN.

f. INSPECTION AFTER EARTHQUAKE

Following any significant earthquake, nominally an earthquake generating a site acceleration of 0.05 gravity or greater, all intake gates and their hoists shall be carefully inspected and trial operated as in Paragraph above, except that the bulkhead must be installed before operating any closure gate.

g. SCHEDULES

See section 5.8 and Volume 6 – Operating and Maintenance Instructions – Intake Gates Bulkhead Trashracks

5.3 HEADWORKS GANTRY CRANE

The gantry crane is supplied for maintenance of the equipment in the concrete headworks. It is designed to handle the ogee spillway stop logs and slot covers, orifice spillway stop logs, power intake trash racks, bulkhead gate and closure gate. The gantry can be used to lower personnel or equipment down the various personnel and equipment shafts. It is self propelled and obtains its electric power from receptacles in the downstream guardrail via a trailing cable. The upstream legs run on the headworks structure deck. The gantry has two hoists – the main hoist with a capacity of 56 tons and an auxiliary hoist with a capacity of 5 tons.

Operating speeds are:

- Main hoist (Raise and Lower)
  
  Fast Speed 3.00 meters per minute
  Inching Speed 0.50 meter per minute
- Auxiliary hoist (Raise and lower)
  Fast speed  10.00 meters per minute
  Inching speed  1.00 meter per minute
- Gantry travel
  Fast Speed  30.00 meters per minute
  Inching speed  1.00 meter per minute
- Trolley travel
  Fast speed  15.00 meters per minute
  Inching speed  1.00 meter per minute

The main hoist can traverse between points 3.00 meters upstream of the upstream parapet wall and 1.10 meters downstream of the downstream gantry rail. The auxiliary hoist is always 1.4 meters downstream of the main hook.

The gantry crane is equipped with flood lights for night operation.

The gantry crane employs lifting or grappling beams to handle the various pieces of equipment. These beams are specially designed for each piece of equipment as follows:

1. Ogee spillway stop logs – beam stored in the ogee stop log slot not occupied by a stop log.
2. Orifice spillway stop log – beam stored on the deck of the orifice spillway structure.
3. Power intake trash racks – beam stored on the deck of power intake structures.
4. Power intake bulkhead gate – beam stored on the deck of the power intake structure.

The power intake closure gate does not need a lifting beam for its removal. However, it has a maintenance support rod to keep it vertical while undergoing repairs.

All gantry crane controls are located within the operators cab on downstream leg. Three men are needed to operate the gantry, one in the cab and the other two moving the trailing cable from one receptacle to another. Additional two men are needed to handle the lifting beams and stop logs. A bell is provided which shall be sounded by the operator immediately before any hoist, trolley, or gantry movement is commence. The gantry should not be operated when the velocity of the wind exceeds 30 kilometers per hour. A wind speed indicator is installed at the spillway gatehouse.

When the gantry is not in use the two parking clamps must be applied. Equipment must not be left suspended from the gantry. If work is interrupted the load must be lowered to the headworks deck.

The detailed methods of handling each piece of equipment with the gantry, a maintenance instructions are given in volume 7 operating and Maintenance
5.4 LOW LEVEL OUTLET GATES – DIVERSION TUNNEL 1

5.4.1 GENERAL

These 3-meter square gates are located at the downstream end of the plug in tunnel 1 in the conduit which passed through the plug. They are accessible from Drainage Gallery E, G via a vertical shaft and gallery. There are two gates in tandem, the upstream gate acting as guard and the downstream gate acting as a control and operating gate.

These gates are only to be operated with the express authority of the Administrator, National Irrigation Administration. The gates are designed to operate at reservoir levels up to Elevation 155.00. When the reservoir level rose to Elevation 155.00, both gates must be closed and can be re-opened when the reservoir falls below Elevation 155.00.

This water outlet through the plug in tunnel 1 is provided to:

- Pass the river flow after Tunnel 2 is closed.
- Control to a certain extent the rate of rise of reservoir during initial filling and to provide continuity of irrigation releases during the period.
- Drawdown the reservoir below Elevation 147.00 if required.

The gates are to be kept in operating condition for several years after which time a decision has to be whether or not to retain the low level outlet.

5.4.2 OPERATION AND ABANDONMENT

As of October 1985, the original hydraulic power unit and controls furnished with the gates were no longer operational. If operation is required, a special hydraulic unit and controls would have had to be obtained for temporary use in the gate chamber.

In December 1985, the condition of the Low Level Outlet Gates and the need for their rehabilitation was critically reviewed by the National Irrigation Administration and its consultants. The consequences of plugging the Low Level Outlet in the 1986 dry season were studied and it has been decided to proceed with removing the gates and plugging the outlets at that time.

5.4.3 ACCESS TO GATE CHAMBER

Access to Gallery G and the vertical shaft is controlled by lockable grille gates at the entrance to Gallery E. Keys to this gate will be release by the DRD Manager to authorized personnel.
5.4.4 SAFETY

A person will not be permitted to enter the gate chamber alone. AT LEAST TWO PEOPLE MUST BE PRESENT ON ANY OPERATING MAINTENANCE OR INSTRUMENTATION VISIT TO THE CHAMBER. Their entry time and expected length of stay must be logged with the officer on duty.

A multi-gas detector is available. Any group entering the shaft must be accompanied by a person trained in the use of this detector. Tests for noxious gases must be made at the top of the shaft, at the bottom of the shaft and in the gate chamber, EACH AND EVERY TIME PERSONNEL VISIT THE GATE CHAMBER, GAS MASKS MUST BE WORN UNTIL IT HAS BEEN PROVEN THAT NOXIOUS GASES ARE NOT PRESENT.

SMOKING, OR THE USE OF MATCHES, LIGHTERS, OR OTHER SPARK PRODUCING DEVICES, IS PROHIBITED IN THE GAS CHAMBER.

5.4.5 LIGHTING AND POWER

Lighting for the vertical shaft and the lower access gallery is controlled by switches located at the top of the vertical shaft. Lighting for the gate chamber is controlled by switches at the entrance to the chamber. The power supply to all operating equipment in the gate chamber is no longer in service. LIGHT POWER SWITCHES MUST NOT BE OPERATED UNTIL IT HAS BEEN PROVEN THAT NOXIOUS GASES ARE NOT PRESENT.

5.4.6 MAINTENANCE

Access into the diversion tunnel is only possible when the level of the river downstream of the dam is less than Elevation 101.00 (the level of the tunnel outlet sill). This river level can be achieved when the power station and the spillway are both closed. Access to the tunnel is also possible only by boat unless the tunnel is first pumped out.

5.5 BALIGATAN OUTLET WORKS

5.5.1 GENERAL

The outlet works exist to supply water to the irrigation system. Water releases are controlled by the power plant turbine and by the outlet works gates. Irrigation water is passed through the outlet works control gates only when either:

- The power plant is closed down, or
- Irrigation requirements are greater than can be supplied through the power plant.
Both control gates are to be operated so that any flow through the outlet works is divided equally between both branches of the outlets. At times it is necessary to close one control gate for repair or maintenance. In this case the entire flow through the outlet works is passed through one branch.

The general arrangement of the outlet is shown on drawing 1202-M-1620

5.5.1 DESCRIPTION

a. TRASH RACK - Refer to drawing 1202-M-1628 the trash rack is located across the ballmouth at the intake structure and serves to prevent large debris from entering the conduct.

b. INTAKE BULKHEAD - refer to drawings 1202-M-1622, 1629, and 1630.

This is installed in a slot in the intake structure its sole use is to close off the conduct to allow it to be dewatered for inspection and maintenance.

c. SPHERICAL VALVE - refer to volume 9 – Operating and Maintenance Instruction – Baligatan O.W. Spherical Valve

This valve serves to close the upstream end of the steel pipeline. It normally operates in the fully open position and it is normally opened or closed under balanced pressure. It is, however, capable of closing against full flow at maximum reservoir head. There is no scour connection at the lowest point of the valve body for removing silt deposits which may build up behind the seal ring, and for draining the valve.

For opening the spherical valve, an oil-operated servomotor is provided. The valve is closed by the counterweight. A mechanical device is provided for manual locking of the valve in the closed position to prevent accidental opening.

There are two by-pass lines installed at the valve the first, from the valve body to the downstream pipeline, serves to fill the downstream pipeline and to equalize the pressure on each side of the main seal, before retracting the seal ring. The second or auxiliary by-pass from the upstream pipeline to the valve body, serves to fill the valve body and to equalize the pressure on each side of the auxiliary seal before retracting the seal ring.

The hydraulic oil system is located in the outlet gate house. It includes an oil tank and a gear type pump. A bladder type accumulator is located in the valve chamber. The oil pump has a capacity of 560 liters per minute which is sufficient to actuate the complete oil pressure system under any operating condition. The pump can be started and stopped manually from the control cubicle in the gate house.

The air vacuum valve in the pipeline downstream of the spherical valve serves to allow air to enter into or exit from the pipeline.

e. CONTROL GATES – Refer to Volume 10 – Operating and Maintenance Instructions – Baligatan O.W. Outlet Gates.

The gates are of sliding vertical lift type with downstream seals. They are completely enclosed within a steel body and are operated by a double-acting hydraulic actuator. They are suitable for continuous operation for long periods of time either partially or fully open under any head up to maximum reservoir level. They are capable of being opened or closed under minimum head. When not in use the gate shall be left partially open with its corresponding guard gate closed. When fully open the gate lip is 30 millimeters below the lintel. A valve is provided in the top cover of the body permit the release of air which may be trapped during filling.

f. GUARD GATES – Refer to Volume 10 – Operating and Maintenance Instructions – Baligatan O.W. Outlet Gates.

These gates of the sliding vertical lift type with downstream seals. They are completely enclosed within a steel body and are operated by a double-acting hydraulic actuator. The gates will normally be either fully open or fully closed and will be operated under pressure. They are, however, capable of being closed in an emergency (inoperative open control gate) under flow at maximum reservoir level. The gates are mechanically retained in the fully open position and in this position the gate lip will be 60 millimeters above the lintel. A by-pass pipe with two valves is provided around each guard gate.

g. GATE HYDRAULIC CONTROL SYSTEM – Refer to Volume 10

There are two hydraulic power units. Each unit powers either of the tandem gates (one control and one guard gate). There is a common oil reservoir for all guard gate). There is a common circuits are interconnected to provide standby operation in case of motor pump failure.

5.5.3 OPERATIONS

Instructions for the operation of outlet works equipment are given in Volume 9 and 10.

a. PREPARATION
Before filling of the conduit downstream of the spherical valve is commenced, the various operating elements shall be in the following condition:

1. Intake trash rack - in position across the bellmouth opening

2. Intake bulkhead - in its raised position and dogged in place. The lowering cable from the top of the dam may be left connected if the cable is not inconvenient or dangerous obstacle in the reservoir. The slot cover at the top of the intake shall be installed and secured in place.

3. Spherical valve - closed

4. Powerhouse inlet valve - closed

5. Outlet works guard gates (upstream gates) both closed

6. Outlet works control gates (downstream gates) both closed

7. Air valve (immediately downstream of the spherical valve) - Adjusted to automatically allow air to be released from the pipeline or to admit air to the pipeline.

b. CONDUCT FILLING

The following steps shall be taken to fill the pipeline

1. Open the by-pass valve at the spherical valve and allow the pipeline to fill. Air displaced from the pipeline will be released through the air valve. The pipeline is full when no air is being forced out of the air valve and initially some water may be forced through the air valve before it seals. The by-pass valve can only be opened manually.

   With the reservoir at Elevation 160.00, it will take approximately 3 hours to fill the pipeline. The reservoir full to Elevation 193.00, it will take approximately 1 hour to fill the pipeline.

2. Open the spherical valve

   For passing water through the stilling basin continue with operations (3) and (4) below. For passing water through the power house refer to separate Baligatan Power plant O & M Manual.

3. Open the by-pass at both guard gates to fill the space between the guard and control gates and balance the pressure across the guard gates.

4. Open both guard gates fully and lock them. The outlet works are now ready for operation.
(5) Open the control gates to the desired opening.

c. NORMAL OPERATIONS – STILLING BASIN RELEASES

The principles of normal operation of the outlet works are explained in Section 5.5.1

(1) Gate Operation

Both the control and guard gates are operated from the gate house.

(2) Valve Operation

The control system will permit either remote control (from the outlet gatehouse) or local control (within the valve chamber). The local control board is provided with push buttons for opening and closing. The desired mode, local or remote, is chosen at the remote control cabinet.

The opening and closing sequence is the same for both remote or local control. A remote “CLOSE” command will override a local “OPEN” signal.

d. FLOOD PROTECTION

There is no capability to spill excess water at Baligatan. For flood operation at Baligatan, the power plant should be operated at maximum capacity regardless of irrigation requirements, once the Magat Reservoir has been filled and water is being spilled over the spillway.

e. EMERGENCY OPERATIONS

The most likely form of an emergency at the outlet works would be as a result of an earthquake which could possibly rupture the conduit upstream of the spherical valve, or the steel pipeline downstream of the spherical valve.

Should the pipeline downstream of the spherical valve be ruptured severely, the pipe burst safety mechanism and the valve will close automatically thus cutting off flow through the pipeline. In case this occurs, pipeline is to be emptied through the control gates and repairs made to the pipeline.

If there is a rupture of the conduit upstream of the spherical valve it is very unlikely that such a rupture would be severe enough to interfere with the operation of the outlet works. In any case, the only way to determine if any damage has been caused to the conduit by an earthquake is to inspect it from the inside. Such an inspection requires the use of divers to install the intake bulkhead to dewater the conduit. When the reservoir is above Elevation 175.00, the divers employed must be
very experienced in deep diving. The conduit is to be examined for damage as soon as possible after an earthquake has occurred.

It is possible that the trash rack at the intake will become blocked with debris. The racks can only be cleared by divers or by shutting down the outlet works, inserting the intake bulkhead and withdrawing the trash racks.

f. TANDEM HIGH PRESSURE GATE OPERATION INSTRUCTIONS

(1) NORMAL OPERATION

(a) Preliminary Check

- Check hydraulic oil level in tank. Be sure level is normal.
- Close valves 23 and 26
- Switch on main circuit breaker Q1
- Check phase voltages. Be sure voltmeter readings are between 456 to 504 volts.
- Check indicating lamps. Note faulty or busted bulbs.
- Be sure spherical valve is open and pipeline is filled with water

(b) GUARD GATE OPERATION

- Perform preliminary checks.
- Open by-pass valve and fill space between guard and control gate. Check opening vent pipes.
- Turn selector switch to "GUARD GATE".
- Check indicating lamps. At this point, AC supply on, DC supply on, Control supply on, gate locked, and water pressure balanced lamps should be lighted
- Disengage mechanical lock of guard. "GUARD GATE" indication should be off.
- If hydraulic oil is cold (below 20 degrees centigrade) warm oil by running pump for about 5 minutes press "PUMP START" button to run pump. "PUMP STOP" to stop pump.
- To raise the gate, press push button "OPEN". Gate position can be read from the position indicator. "GATE IN TRANSIT" indication light is on while gate is moving.
- To stop the gate, press "STOP" button. Gate automatically stops when reaching fully opened or closed positions.
- To lower gate, press push button “CLOSE”

- Lock gate in fully opened position by placing the mechanical lock.

(c) CONTROL GATE OPERATION

- Perform preliminary checks. GUARD GATE should be open.

- Set selector switch to “CONTROL GATE”

- To raise gate, Press button “RAISE”

- To lower gate, Press button “LOWER”

- To stop gate, Press push button “STOP”. Gate automatically stops when reaching fully opened or closed positions.

- After operation, turn off main switch Q1 and lock cabinet.

(2) MANUAL OPERATION

(a) BRANCH I GUARD GATE

RAISE

1. Check hydraulic oil level. Be sure its normal

2. Open by-pass valve and fill space between guard and control gates.

3. Open vent pipes to release air and further check water pressure balanced condition.

4. Disengage mechanical lock.

5. Open two-way valves 10.1 and 11.3a

6. Open ball cock 26.1

7. Open valve 23.

8. Place hand pump handle and operate hand pump.

   Adjust pump pressure as necessary by turning regulating knob of hand pump.

9. Note gate opening at the position indicator.

10. Lock gate at fully opened position.

LOWER

- Shift lever of two way valve 11.3 to normal position

- Open two-way valve 10.3b.

- Operate hand pump. Regulate pressure as necessary.

- Shift two-way valve levers to normal position

- Close ball cocks 26.1 and 23
(b) BRANCH 1 CONTROL GATE

RAISE

- Close two-way valve 11.3b.
- Open two-way 11.1a.
- Operate hand pump. Regulate pressure as necessary. Note opening from the position indicator.

LOWER

- Shift lever of two-way valve 11.1a to normal position
- Open two-way valve 11.1b.
- Operate hand pump.

(c) BRANCH 2 GUARD GATE

RAISE

1. Do steps 1 to 4 as in Branch 1 raise procedure.
2. Open two-way valves 10.2 and 11.4a
3. Open ball cock 26.2
4. Open valve 23.
5. Operate hand pump. Adjust pressure as necessary. Note gate position from the indicator.

LOCK gate at fully opened position.

LOWER

- Shift lever of two-way valve 11.4a lever to normal position.
- Open two-way valve 11.4b.
- Operate hand pump. Adjust pressure as necessary. Note gate from the indicator.

(d) BRANCH 2 CONTROL GATE

RAISE

- Shift two-way valve 11.4b lever to normal position.
- Open two-way valve 11.2a
- Operate hand pump. Adjust pressure as necessary. Note gate position from the indicator.

LOWER

- Shift two-way valve 11.2a lever to normal position.
- Open two-way valve 11.2b.
- Operate hand pump. Adjust pressure as necessary. Note gate position from the indicator.
- After operation, shift levers of all two-way valves to normal position.
- Close ball cock 26.2 and 23.

f. SPHERICAL VALVE OPERATING INSTRUCTIONS

- Pre-start conditions
  - Tandem High Pressure Gates CLOSED
  - Power plant Butterfly Valve CLOSED
  - Auxiliary Solenoid-operated Shutoff Valve of Spherical Valve Hydraulic Line CLOSED
  - Drainage valves 1101, 1405 CLOSED
  - Upstream Seal ring retracted
  - Main Seal ring CLOSED
  - Pipe burst safety device not released

(1) PRELIMINARY CHECK

1.1 Check hydraulic system including line valves.

Normally Closed: 6201, 6211, 6213, 6601, 6201
Normally Open: 4106, 6102, 6103, 6204, 6205, 6210, 6212, 6215

1.2 Check water line valves

Normally Closed: 1101, 1502, 1400, 5402, 5404
Normally Open: 5401, 6904

- Open by-pass valve 5402. Fill pipeline with water. Monitor the Air-Vacuum Valve while filling the pipeline.
- Readings on Pressure gauges 6901 and 6902 could be equal even if the pipeline is NOT FILLED with water. "Water Pressure Balanced" indicating light might be ON too. To check the actual situation, OPEN the vent valve at the top of the Spherical Valve body. Either compressed air or water will be discharged.
- Close by-pass valve 5402 if continuous flow of water already exits from the vent valve.
- Switch on main circuit breaker Q1. Check Voltage readings. Be sure it is within the operating range 456 to 504 volts. At this point, indicating lamps for AC supply on, DC supply on, control supply on and water pressure balance should be lighted.

(2) REMOTE OPERATION

(a) OPEN
When the pre-start conditions have been satisfied and after doing the preliminary check, set selector switch in the remote control board to “Remote”.

- Press button “VALVE OPEN”
- The Spherical Valve automatically stops when fully open.
- Energize the Auxiliary Solenoid Valve near valve 4106.
- Main switch Q1 may now be switched off.

(c) CLOSE

- Option 1 – by de-energizing Auxiliary Solenoid Valve
- Option 2 - Press button “VALVE CLOSE”

(3) LOCAL OPERATION

(a) OPEN

- After doing the preliminary check, set selector switch in the remote control panel to “LOCAL”.
- From the local control board, press button “VALVE OPEN”. Valve automatically stops when fully opened.

(b) CLOSE

- Press button “VALVE CLOSE”. Valve automatically stops when fully closed.

5.5.4 MAINTENANCE

a. INTAKE BULKHEAD

This is lowered in place only when it is desired to close off and empty the concrete conduct upstream of the spherical valve. The bulkhead is dogged in position at the top of the intake tower. A winch is needed and must be located on top of Baligatan Dam as shown on drawing 1202-M-1630. A diver is needed to check condition of the winch wire rope which is attached to the top of the bulkhead and to remove the dogging mechanism. When this is done, the bulkhead can be lowered into place. The bulkhead is a slide gate and will not close against flowing water. It has a small filling valve installed. This valve allows the conduct upstream of the spherical valve to be filled with water thus balancing the pressure across the bulkhead and allowing it to be removed. The filling valve can only be operated manually from inside of the conduit. It is 50 millimeter valve, and with the reservoir at Elevation 160.00, it takes 21 hours to fill the conduit upstream of the spherical valve.
b. EMPTYING THE CONDUITS

(1) Downstream of the spherical valve

- Shut down the turbine and/or the outlet gates
- Close the spherical valve
- Open the outlet gates to drain the pipeline

(2) Upstream of the spherical valve

- Shut down the turbines
- Close the outlet gates
- Lower the intake bulkhead into place
- Close the filling valve in the intake bulkhead
- Open the outlet gates to drain the conduit when maintenance or repair work is being carried out in the conduit upstream of the spherical valve, the valve and the control and guard gates must all be open. Also the conduit must be continuously monitored for gas that may be released into the conduit from water leaking past the intake bulkhead.

c. REFILLING THE CONDUIT

- If only the conduit downstream of the spherical valve has been emptied, then all that needs to be done is to close the outlet gates and by-pass water around the valve to fill the pipeline and then open the valve.
- After complete emptying of the conduits, the following steps shall be taken for refilling:

  - Enter the conduit through the manhole and through the spherical valve
  - Proceed to the intake bulkhead gate and open the filling valve fully
  - Return to the manhole, exit from the pipeline, and close the manhole
  - Close the spherical valve.
  - Fill the conduit upstream of the spherical valve.
  - Remove the intake bulkhead gate
  - Close the guard and control gates.

  The outlet works system is then in the status required for filling as defined under 5.5.3 b- CONDUIT FILLING. The pipeline shall then be filled as described under initial filling.

d. NORMAL MAINTENANCE

Detailed instructions for normal maintenance are given in Volume 9 and Volume 10. In addition, once each 3 months, the control gates and the guard gates and the spherical valve shall be inspected and operates through a complete cycle, CLOSED – FULL OPEN – CLOSED. When the control gates are being operated, the guard
gates shall be closed. When the guard gates are being operated, the control gates shall be closed. When the spherical valve is being operated, the control gates shall be closed.

e. **INSPECTION AFTER EARTHQUAKE**

Following any significant earthquake, nominally an earthquake generating a site acceleration of 0.05 gravity or greater, all gates and hoists, the pipeline and the spherical valve shall be inspected and trial operated as described in 5.5.4.d — NORMAL MAINTENANCE. The conduit upstream of the spherical valve shall be inspected as discussed in 5.5.3.e — EMERGENCY OPERATIONS.

f. **SCHEDULE**

See Section 5.8 INSPECTION AND TRIAL OPERATION SCHEDULES FOR EQUIPMENT and Operations and Maintenance Instructions in Volume 9 and 10

5.6. **MARIS DIVERSION DAM**

5.6.1. **GENERAL**

Maris Diversion Dam serves as re-regulation dam to regulate the water release from the Magat Hydroelectric Plant. The hydroelectric plant will operate as a peaking plant during the dry season and power output varies from the maximum available to zero. Although the daily total volume of water released from the Magat Hydroelectric Plant in the dry season normally is limited to the daily irrigation demand, it is necessary to store the water at Maris so that it can be released uniformly over 24 hours to suit irrigation needs.

5.6.2. **OPERATION**

The storage capacity of the Maris Reservoir with the dam crest at Elevation 102.00 is sufficient to store the daily IDR of its service area. Whenever the MHEPP is operating in the peak mode, it is necessary to increase the storage capacity of the Maris reservoir by lowering the stop logs especially during the drawing down period. Also, in the event that NIA allows SNAP to release additional discharge on top of the IDR during the drawing down period, SPILLAGE OVER THE STOP LOGS (105 MASL) SHALL NEVER BE ALLOWED.

Under normal situation, NIA shall strictly operate the twelve (12) gates in accordance with the established discharge rating table to maintain a more or less constant discharge.
5.6.3. STOP LOGS

There are 16 steel logs each 12.00 meters wide by 3.00 meters high which can be dogged at the tops of the piers. They can be lowered to the dam crest by the traveling gantry and when they are completely lowered, the crest of the dam is raised to 105 MASL. As soon as additional daily storage is no longer required, the stop logs shall be raised to the top of the piers before there is any danger of them being overtopped by excess river flows. They should be withdrawn no later than when the Magat Reservoir has reached Elevation 175.00 in its refilling cycle. In the event, however, that SNAP as dictated by their alternate peaking and off-peak operations requires the lowering of the stop logs to maintain the minimum required elevation at the Maris dam without spilling at any given time during the off-peak operation, the stop logs shall be lowered.

5.7. BALIGATAN DIVERSION DAM

This dam is designed to divert the Irrigation water which has been released from the Magar Reservoir through the Baligatan Outlet Works into the Irrigation canals. The dam has an overflow ungated spillway which will pass excess flows, and a sluiceway controlled by a radial gate. The sluiceway is provided to scour silt deposits from the vicinity of the canal intakes on the right side. The intakes are controlled by regulating sluice gates.

5.7.1 CANAL INTAKE GATES

There are eight gates each 1.45 meters by 1.45 meters. The gates are hand-operated and may be operated for long periods at any opening. The gates and frames are of cast iron with bronze sealing strips. They shall be operated as required to release the desired amount of water into the irrigation canals.

5.7.2 RADIAL GATE

This gate is 5.25 meters wide and 3.00 meters high. The radial gate is operated by an electrically powered wire rope hoist. It is opened under power by will close under its own weight. It can be operated at any opening for long periods. When closed, the top of the gate seals against a lintel beam.

There is a bulkhead gate provided which allow the radial gate to be dewatered for maintenance. The bulkhead needs to be placed or removed by a mobile crane or a 10-ton chain block. It can only be placed or removed when the radial gate is closed. The bulkhead is fitted with a by-pass valve which will allow the space between the gates to be flooded and thus permit the removal of the bulkhead. For storage, the bulkhead is dogged at the top of its shaft. They bulkhead cannot be used when water are above the normal operating level of Elevation 128.40.

The radial gate shall be operated once each six months, or more often if experience shows it to be desirable, to scour any silt deposits from the canal intake area.
5.7.3 OPERATION AND MAINTENANCE

Detailed instructions are given in Volume 12 Operating and Maintenance Instruction – Baligatan Diversion Dam Gates

5.8 INSPECTION AND TRIAL OPERATION SCHEDULES FOR EQUIPMENT

The following schedule gives the recommended frequency of inspection and trial operation of equipment at Magat:

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Item</th>
<th>Recommended Frequency</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Ogee Spillway gates</td>
<td>3 Months</td>
<td>Trial Operates</td>
</tr>
<tr>
<td>2.</td>
<td>Orifice Spillway gates</td>
<td>12 Months when the reservoir is at low level. 5 years</td>
<td>Trial Operates behind stop Logs</td>
</tr>
<tr>
<td>3. Power intake trash racks</td>
<td>Annually when reservoir is at low level or excessive head loss is indicated.</td>
<td>Racks need to be withdrawn for cleaning. SNAP to Request for cleaning</td>
<td></td>
</tr>
<tr>
<td>4. Power intake closure</td>
<td>3 months</td>
<td>Trial operation by NIA</td>
<td></td>
</tr>
<tr>
<td>5. Headworks metal work including gate logs</td>
<td></td>
<td>Install stop logs or bulkhead to inspect upstream faces repaint as necessary.</td>
<td></td>
</tr>
<tr>
<td>6. Tunnel 1 outlet gates</td>
<td>Not Applicable</td>
<td>Gates removed and outlet plugged</td>
<td></td>
</tr>
<tr>
<td>7. Tunnel invert downstream</td>
<td>Not Applicable</td>
<td>Gates removed and outlet plugged</td>
<td></td>
</tr>
<tr>
<td>8. Baligatan Spherical Valve and outlet gates</td>
<td>3 Months</td>
<td>Trial Operate</td>
<td></td>
</tr>
<tr>
<td>9. Baligatan Metal Work</td>
<td>Annually</td>
<td>Repaint as necessary</td>
<td></td>
</tr>
</tbody>
</table>
including metal work and gates

10. Emergency power generator at left interface

Monthly Trial Operate and load up

Weekly Start and warm engine

11. Gantry Crane Weekly Trial operate

----------------------------------------

Detailed maintenance schedule for each item of equipment are given in the operating and Maintenance Instruction contained in Volume 5 to 13 of this Manual.

5.9 MAJOR EQUIPMENT SUPPLIERS NAMES AND ADDRESSES

The addresses and telex numbers of the supplier of the major mechanical equipment in the Magat Dams Complex are listed below for ready reference.

<table>
<thead>
<tr>
<th>Equipment Description</th>
<th>Supplier Name</th>
<th>Address/Contact Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orifice Spillway Gates and Stop Log</td>
<td>Voest Alpine AG</td>
<td>Postfac 2 A-4010, Linz, Austria</td>
</tr>
<tr>
<td>Baligatan Outlet Spherical Valve</td>
<td>Kurimoto Ltd.</td>
<td>No. 1-9 Shimbashi 4, Tokyo, Japan</td>
</tr>
<tr>
<td>Tandem High Pressure Outlet Gates</td>
<td></td>
<td>Chome, Minato-Ku</td>
</tr>
<tr>
<td>Diversion Tunnel Low Level Outlet Gates</td>
<td></td>
<td>Telex J 24946</td>
</tr>
<tr>
<td>Ogee Spillway Gates and Stop Log</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power Intake Closure Gate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bulkhead and Trash Rack</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traveling Gantry Crane</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Substation Equipment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baligatan Diversion Dam Radial Gate and Stop Log</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baligatan Diversion Dam Canal Intake Gates</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caterpillar Emergency Power Unit</td>
<td>Distributed by:</td>
<td>USIPHIL, Makati, Metro Manila</td>
</tr>
<tr>
<td>Baligatan Outlet Works Intake</td>
<td></td>
<td>Hydro Resources Contractors Corp.</td>
</tr>
<tr>
<td>Bulkhead and Trashrack</td>
<td></td>
<td>Ugong, Pasig, Metro Manila</td>
</tr>
<tr>
<td>Maris Stop Logs</td>
<td></td>
<td>L. P. Engineering</td>
</tr>
<tr>
<td>Maris Gantry Crane</td>
<td></td>
<td>Plaridel, Bulacan</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Engineering Eqipt.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ugong, Pasig, Metro Manila</td>
</tr>
</tbody>
</table>

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Chapter 6

INSTRUMENTATION

6.1 GENERAL

Instrumentation as discussed herein refers to a variety of devices which serve to measure the structural behavior of dams and their appurtenant structures. Dam instrumentation is necessary to monitor its performance during construction, initial filling and the subsequent long term operation. Instrumentation provides a means of detecting the development of abnormal conditions before they lead to major problem.

The Magat Dam is equipped with a high degree of instrumentation of varying degrees of sophistication and accuracy. Proper collecting, reducing, recording, plotting, analyzing and interpreting of the data from this instrumentation is needed to determine that the dam, dykes, foundation, abutments and appurtenant structures of the Magat Dam Complex are performing in a safe manner as designed. Inspections, as detailed in Chapter 7, are essential to complement the instrumentation data.

This chapter describes the types and purposes of the Magat Instrumentation and also addresses procedure and frequencies for data collection and reduction, data recording, plotting, and filling, data evaluation and interpretation. Timely evaluation of the instrumentation data is essential for detecting an abnormal condition and for early effective corrective action.

6.2 TYPES AND PURPOSES OF MAGAT INSTRUMENTATION

6.2.1 TYPES OF INSTRUMENTS INSTALLED

The types of instruments installed at the Magat Dam Complex are:

a. Piezometers (Vibrating Wire, Pneumatic, Hydraulic, and Standpipe Types)

b. Soil Pressure Cells

c. Torpedo Inclinometer Casings

d. Extensometers and Associated Overflow Settlement Cells

e. Double Fluid Settlement Devices (with Automatic Plotters)

f. Inverted Plumblines (Pendulums)

g. Surface Settlement and Deflection Measurements
h. Strong Motion Accelerograph and Peak Acceleration Recorders
i. Flow Measurement Weirs
j. Movement Recording Devices at Low Angle Shear. The principles of operation, data collection and reduction procedure and analysis of data quality and validity are discussed in detail in Volume III, Instrumentation, of this Manual (referred to hereafter as the Instrumentation Manual) and which is an integral part of this O&M Manual.

Notes:

The SEEPAGE MEASURING WEIR OPERATIONAL MANUAL, dated January 28, 1982, provides general information with respect to procedures for installing calibrating and reading weir data as well as recording weir discharges.


6.2.2 PURPOSES OF INSTRUMENTS

The general purpose of the instrumentation installed in the Magat Dam Complex and procedure for operating and maintaining the equipment as appropriate are as follows: (Note: For details regarding the specific instruments and instructions for use and maintenance, see the instrumentation users manuals prepared by the suppliers. These manuals are included in the Manual as Volume 4).

a. PIEZOMETERS

Piezometer observations provide data as to the water pressures at selected points within the embankments and the foundation. The following are general comments regarding the four piezometer types installed at Magat:

(1) ELECTRIC VIBRATING & WIRE PIEZOMETERS

There are two types of electric vibrating wire piezometers used in the project: the sustained reading type manufactured by TELEMAC and designated by a “Pa” prefix and the non-sustained reading type manufactured by SOIL INSTRUMENTS and designated by a “Pe” prefix.

The Instrumentation Manual describes the principles of operation of these piezometers. With respect to maintenance, none is necessary, or in fact possible, for the piezometers themselves. Any exposed cable leads should be kept clean and protected from environmental effects. If a non-sustained piezometer (Pe type) becomes inoperative it is usually due to instrument malfunction or broken cable leads. Generally, the instrument has to be abandoned unless the malfunction can be traced to an accessible cable break.
An accessible cable break can be repaired by soldering and the splice reinsulated. Also, there may be a “slip” in readings which does not involve a complete instrument failure. In this case, readings and analysis can be continued on a relative basis with a notation regarding the magnitude of the estimated “slip”, which generally can be verified by comparison with readings from nearby piezometers and by sounding to detect if the housing had been filled with water. If a sustained reading piezometers (Pa type) apparently fails, sometimes it is possible to obtain readings in the non-sustained mode. Otherwise the instrument will have to be abandoned.

(2) PNEUMATIC PIEZOMETERS

Gloetzl pneumatic piezometers marketed by TERRAMETRICS and designated by the “Pb” prefix are used in Magat. The instrument measures water pressure acting on one side of a diaphragm by applying an equal pneumatic pressure to the backside of the diaphragm. Poor readings may result if water condensate accumulates in the lines normally indicated by moisture outflow from the return, slow response and reading variations when repeated. If such symptoms are observed, the lines should be flushed with nitrogen (the recommended gas) or dry air until all water is expelled. When these instruments become inoperable, it is usually due to a rupture of the diaphragm or a large leak in a buried line, in which case, the instrument unfortunately has to be abandoned. If the pneumatic lines become obstructed by foreign particles, readings sometimes can be obtained by reversing the input and output lines.

(3) HYDRAULIC PIEZOMETERS

The hydraulic piezometers used at Magat were manufactured by SOIL INSTRUMENTS and are designated by a “Po” prefix. The principle of operation is to measure the water pressure acting at the instrument location by a continuous column of water extending to a Bourdon Gauge at the reading point. The difference in elevation between the piezometer tip and the reading location must be known to determine the water pressure at the instrument location from the gauge reading. The column of water must not be broken and should be free of air. Therefore, it is essential to de-air the system whenever bubbles are noted in visible tubing or when the two tubes of any instrument register different pressure when connected individually to the measuring gauge. Procedural guidelines and discussions of the desired operation are presented in Section 1C1 ON Pages A-B and 9 of the Instrumentation Manual. Section C2 of the Instrumentation Manual provides details of the De-Airing Unit. Aside from the above and repairing accessible broken hydraulic lines, no other maintenance is necessary.
(4) **STANDPIPE PIEZOMETERS**

These open-well type piezometers were manufactured on site. Standpipe piezometers are designated by either a “Pd”, “BSP” or “MSP” prefix. The reading is obtained by measuring the water level within the piezometer connector pipe. The measured water level is the piezometric head at the top of the perforated section of the pipe which is in general the same as the bottom of the packer or seal in the casing. Also, there are standpipe type piezometers in the drainage galleries (designated Pd) and in the concrete headworks structures (designated “U” for uplift devices). Uplift devices and standpipe piezometers in the galleries generally cannot be measured in the open-well condition as due to their elevations, water often flows continuously from them. Readings from these uplift devices and any flowing standpipe piezometers elsewhere are taken with a Bourdon Gauge. Readings from the uplift devices should be taken by sounding if they are not flowing.

The only maintenance required for the standpipe piezometers is to flush or rod the casing clear should they become plugged, or redrill if either of the above is unsuccessful. Protective covers (valves or caps) should be repaired or replaced as necessary.

b. **SOIL PRESSURE CELLS**

Gloetzl type soil pressure cells marketed by TERRAMETRICS INC. were installed at various elevations along the left and right interfaces between the concrete headworks and the embankment sections. These total stress cells are oriented both vertically and horizontally. The principle of operation for these instruments is basically the same as for the pneumatic piezometers (applying fluid pressure to one side of the diaphragm equal to the stresses acting on the other side) except that the pressure-transmitting medium used is a kerosene and oil mixture. These instruments are discussed in detail on pages A-11 through A-14 of the Instrumentation Manual.

The soil pressure cells were installed to measure the vertical and lateral earth pressure exerted immediately adjacent to the interface walls. The platelike stress cells mounted on the nearly vertical interface structure walls measure the total lateral earth pressure exerted at the interface and the horizontally oriented stress cells which have been placed within several meters of the walls measure total vertical pressure. The total pressure measured by these instruments comprise both earth pressure and pore water pressure. Therefore, each instrument was installed with a companion pneumatic or hydraulic piezometer for measuring pore water pressures. By deducting the pore water pressure from the total stress cell reading, the lateral or vertical effective stress by the overlying embankment fill are determined.
These instruments are buried in the dam and thus are not accessible. The only maintenance possible is at the connection points. These should be kept clean and serviceable at all times and should be repaired or replaced if damaged.

c. **TORPEDO INCLINOMETER CASING (TIC)**

The torpedo inclinometer casings installed at Magat were manufactured by the SLOPE INDICATOR CO. (SINCO). These are designated on the drawings by the prefix “TIC”. Each installation consists of a various number of approximately 1.50 meter long casing sections which have been connected with telescoping couplings thus allowing casing sections to move vertically relative to one another.

The TIC installations are used to measure both vertical settlements and lateral movements occurring at selected points along the casing and can be used as open well standpipe piezometers.

Lateral movements are determined by measuring inclination of the casing sections. Ideally measurements are taken at the same vertical location each time. By knowing the distance between reading locations and the measured inclination of all section of the casings, the deflected profile of the inclinometer is obtained. Comparison of this profile with the original profile yields data on lateral movements along the entire casing. Lateral movements are determined in two directions: one parallel to the axis of the dam and the other at right angles to the axis.

Vertical settlement measurements are taken at the bottom of each section relative to the top of the installation.

The TIC installation should not require much maintenance. Protective covers should be repaired. The primary cause of defective TICs after installation is foreign matter becoming lodged within the casing thereby obstructing the passage of the measuring probe. In the event that blockage of the inclinometers is suspected, two remedies for the situation are possible. The possible remedies are:

- fish or float the obstruction out; or
- force the obstruction with a dummy probe which is made specifically for this purpose

(Note: MEASUREMENT PROBES SHOULD NOT BE USED)

If the obstruction cannot be removed, it will be necessary to abandon the instrument relative to readings below the obstruction.)
d. EXTENSOMETERS

SOIL INSTRUMENTS LIMITED extensometers have been installed at various levels of the left and right interfaces between the concrete headworks and abutting embankment sections. The extensometers are anchored to the concrete headworks wall and extend out in a horizontal direction into the fill. The extensometer assemblies consist of one or more double transducers, one or more plates, and P.V.C. protected steel rods which connect the component parts into a continuous unit. In addition, the assemblies have been equipped with overflow settlement cells to measure the settlement at the concrete wall and at the location of the first transducer. The Instrumentation Manual provides detailed discussion on extensometer assembly, principles of operation, and installation.

The extensometer assemblies are intended to provide deformation data on the embankment fill adjacent to the nearby interface walls. Moreover, extensometer data and stress cell readings are intended to complement each other. The former measures vertical and horizontal deformations whereas the latter measures vertical and horizontal stresses along the embankment/concrete wall interface.

Since these instrument assemblies are buried within the fill, there is little maintenance that can be done. Broken electrical or hydraulic lines should be repaired if accessible. All connections should be kept clean and in “like new” condition. As a new part of regular maintenance, a fungicide should be flushed through the overflow settlement cell lines to prevent the build up of algae which could block the lines or clog the settlement cell.

e. DOUBLE FLUID SETTLEMENT DEVICES (DFSD)

DFSD systems manufactured by SOIL INSTRUMENTS are installed at various levels within the embankments. A comprehensive description, diagram, and operational procedures are discussed on pages A-19 through A-24 of the Instrumentation Manual.

The DFSD installations measure the settlement occurring along selected alignments of the embankment sections. The relative deformations along the selected alignments can be measured continuously from the beginning of placement of fill throughout the period of operation.

System operation and maintenance, including maintenance of the readout unit are discussed in Section C of the Instrumentation Manual.
f. INVERTED PLUMBLINES

These instruments are located in the ogee spillway, orifice spillway and power intake concrete structures. As the name implies, they are simply pendulums which are inverted. That is, the fixed point is at the bottom of the installation with the top free to move horizontally. The top consists of a float type assembly wherein the buoyancy ensures that the steel wire of the pendulum is kept taut.

The inverted plumbline is designed to allow measurement of deflections of the concrete structures by monitoring the movements of the taut pendulum wire with respect to an imaginary reference line on the concrete structure. Measurements of offset from vertical are typically taken at several intermediate elevations along the inverted pendulum assembly. The measurements of the movements of the taut wire are made by optical telescope in the two orthogonal horizontal axes. From these measurements, horizontal movement at instrument reading points relative to the base can be determined.

The measuring frames on which the reading telescopes are mounted should be kept clean, dry and slightly oiled to prevent rusting. Moreover, the steel frame telescope carriage should not be allowed to loosen from its initial present position. If it does, then the frame should be repositioned precisely so that the axes are mutually perpendicular and lie in the same horizontal plane before securing again. Maintenance on the pendulum assembly consists of the following:

- ensure that there is sufficient water in the head assembly to keep the steel wire taut
- ensure that there is an oil film layer over the water in the float chambers.
- Ensure that the head assembly is free to move.
- Ensure that rusting is not occurring at the base anchor, the measuring frames, the wire or any other element of the system.
- Repair float assemblies which are leaking or stuck.

8. SURFACE SETTLEMENT AND DEFLECTION MEASUREMENTS

A total of one hundred forty-four (144) externally located settlement and deflection monitoring points or monuments are installed on the structures. They are:

- 110 Surface Measurement Points (SMP-)
- 9 Triangulation points (C)
- 12 Instrument Observation Stations (IOS)
- 10 Torpedo Inclinometer Casing Installation (TIC)
The monuments are designed to measure settlements and deflections at the structure surface. The measurements are made by precise surveys relative to fixed locations.

The survey monuments should be kept in “like new” condition. Broken or vandalized monuments or points should be repaired or replaced as soon as possible and new baseline readings established for future reference.

h. **STRONG MOTION ACCELEROGRAPHS AND PEAK ACCELERATION RECORDER**

There is a strong motion accelerograph on the dam crest at Section MA and another installed in drainage Gallery K. In addition, there are three peak acceleration recorders, one installed near the concrete right interface structure and two on Section MA. These instruments record accelerations digitally and on graph paper. This seismic instrumentation requires specialized maintenance.

i. **FLOW MEASUREMENT DEVICES**

(1) **Seepage Measuring Weirs**

A total of 24 flow measurement weirs have been installed at the Magat Dam Complex. Ten of these are located in the drainage galleries beneath the Magat dam and headworks structures. All the weirs were manufactured at site and are sharp crested V-notch weirs.

Details of weir and stilling well dimensions along with instructions for calibrating, reading and maintaining are contained in the SEEPAGE MEASURING WEIR OPERATION MANUAL, Appendix, Volume 3.

The purpose of the foundation weirs is to measure the total flow exiting from selected sections of structures. For example, the relation of weir MWK-2 with respect to MWK-1 is intended not only to measure the accumulated seepage upstream of MWK-2 but also to distinguish how much seepage is occurring in the drainage gallery reach between MWK-1 and MWK-2. Thus, the intercepted foundation seepage is monitored by measuring flow quantities within selected segments.

Flow pipes have been installed in DGK (S) and the low angle shear exploratory adits. These, like the weirs, measure cumulative flows in sections of the drainage galleries. They are used instead of weirs because flow rates are too small to be measured accurately by overflow weirs.

The purpose of the other weirs which are located outside of the plan limits of the dams and dykes is to assess seepage flows from the downstream toe of these embankments.
The maintenance of flow measurement devices consists primarily of ensuring their continued "like new" condition. The approach channels and stilling basins should be kept free of debris and accumulated sediments. Moreover, the as-built geometry should be maintained. The weir plates should be inspected periodically for knicks and distortions. Small knicks or burns can be filed flush to the design surfaces but small dents in the plate can be ignored. Large dents or distortions of the weir plate will require replacement of the unit and recalibration.

Flow pipes should be kept clear of obstructions and be free from holes or leaks. The maintenance of drain holes is discussed in Chapter 7, Section 7.3.1

(2) Baligatan Drain Holes

A total of ninety (90) holes were installed along the downstream toe of the Baligatan Dam and Connecting Dyke of which at least seven (7) have become clogged. Although the purpose of these holes is to relieve water pressures in the foundation, they can be used for volume measurements of the quantities of seepage flowing through the foundation when the water is overflowing from the top of the standpipe installed on the top of the hole. This is done by checking the time required to fill a container with specific volume of water.

The drain holes shall be kept covered and shall be kept free of obstructions or clogging as much as possible.

6.3 INSTRUMENTATION BY PROJECT FEATURE

In the previous section, the types and purposes of the instrumentation installed in the Magat Dam Complex have been discussed. This section summarizes the installed instrumentation by project feature.

6.3.1 EMBANKMENTS

Key embankment sections have been equipped with a wide variety and high density of instrumentation devices. These devices are designed to measure:

- Piezometric head at various elevations and within various zones of the embankments along the embankment interfaces with the concrete structures and within the rock foundation underlying the embankments.
- Total and effective lateral soil pressure, overburden stresses and soil strains at or adjacent to concrete/soil interfaces.
- Settlements within the embankments and differential settlements between adjacent embankment zones.
- Horizontal movements of embankments surface points.
- Earthquake induced acceleration of the embankment crest and in the foundation.
The following is a summary of the instrumentation installed for monitoring performance of the embankments including a brief discussion of prime concerns at each location:

a. LEFT INTERFACE – refer to as-built drawing No. AB 1202-C-276

2 - Extensometer Assemblies
4 - Lateral soil Pressure Cells with pneumatic piezometers
4 - overburden soil pressure cells
9 - hydraulic piezometers

Of prime concern is the maintenance of good contact between the concrete interface wall and the soil embankment. By measuring the lateral soil pressure acting on the wall (soil pressure cells), the pore pressure along the interface (piezometers) and the overall deformation pattern of the soil adjacent to the interface (extensometer), an evaluation can be made of the contact between the embankment and the concrete wall.

b. RIGHT INTERFACE – refer to as-built drawing No. AB 1202-C-3275

6 - extensometer Assemblies
8 - lateral soil pressure cells with pneumatic piezometers
6 - overburn pressure cells
11 - double fluid settlement device loops
21 - hydraulic piezometers

Again the prime concern is the maintenance of good contact between the concrete wall and the embankment as discussed in the previous section pertaining to the left interface. The DFSD loops extending from the right interface into the embankment provide additional data on settlements within the embankment particularly differential settlements.

The DFSD loops at elevations 142.00 and 188.00 extend out to the embankment maximum section (Section MA) and thus provide data on settlements within this key portion of the embankment.

c. MAIN DAM MAXIMUM SECTION (MA) – refer to as-built drawings No. 1202-C-3247, and No. AB 1202-F-C=1072

35 - piezometers located in the section
7 - piezometers offset from section MA (PEUB series plus PeX1, PaX3 and PaX4)
16 - standpipe piezometers installed in the switchyard area (PDSA and DGM series)
4 - torpedo inclinometer casings
5 - DFSD loops (two extending into this section from right interface)
5 - instrument observation stations
1 - strong motion accelerograph
2 - peak acceleration recorders
Of prime matter of interest for the embankment at this section MA are the distribution of pore pressures in the various fill zones of the dam, and the deformations, both horizontal and vertical of the embankment due to various loading combinations.

The distribution of embankment piezometers in this section provides data on the variation of pore water pressures across the various zones of the dam. The piezometers in the rock foundation provide similar data for the foundation. Together they serve to illustrate the flow pattern through and below the dam.

Vertical and horizontal movement can be determined by monitoring data from the DFSD loops, the TIC installations, the Instrument Observation Stations and the other surface measurement points discussed later in this section.

The accelerograph and the peak acceleration recorder will provide records of earthquake induced acceleration of this section of the dam.

d. MAIN DAM CONSTRUCTION JOINT (Section MB) – refer to as-built drawings No. AB 1202-C-3247A and AB 1202-C-3277.

36 - piezometers
3 - torpedo inclinometer casings
2 - DFSD Loops (one extending into this section from section MA)
3 - instrument observation stations

The discussion for section MA regarding concerns and determination that can be made from the instrumentation data applies equally to this location. In addition, the DFSD Loops extending from section MA to section MB provide data on the relative settlements on the two slides of the construction joint.

e. MAIN DAM ABUTMENT-STATION M2 + 064 and B0 + 204/214 refer to as-built drawing No. AB 1202-C-3241

6 - standpipe piezometers

The piezometers at this location measure the water pressure in the area of contact between the Magat Dam and abutment. Unusually high water pressure could be indicative of excessive seepage (or leakage) in the abutment contact area.

e. BALIGATAN EMBANKMENT DAM AND DYKES – refer to as-built drawings No. AB 1202-C-3228, AB 1202-C-3229, AB 1202-C-3235, and AB 1202-C-3236.

91 - piezometers
3 - torpedo inclinometer casings
2 - DFSD Loops
4 - Instrument Observation Stations
The prime concerns regarding the Baligatan Dam and dykes are the same as those for the Magat Dam.

The series of standpipe peizometers and drain holes which are located along the downstream toe of the Baligatan Dam and dykes, provide information on the uplift pressures at the embankment toes. The piezometers at sections DB, DA, BA, and BD provide data on pore pressure within the zones of the embankments. The DFSD loops provide information on vertical deformation (particularly differential settlements) and the observations from the TICs and instrument Observation Stations provide data on horizontal and vertical movements.

g. **SURFACE DEFLECTION MEASUREMENTS** – REFER TO AS-BUILT DRAWINGS No. 1202-C-3209A and AB 1202-C-3209B

10 - surface measurement monuments
10 – torpedo inclinometer casings (also listed previously under other paragraphs above)
12 – instrument observation stations (also listed previously under other paragraphs above)

All of the above listed 132 measuring points should be surveyed to provide data relative to the horizontal and vertical movements at the surface of the dam at the location of each of the installed points.

h. **SURFACE FLOW MEASUREMENT WEIRS** – refer to as-built drawings No. AB 1202-C-3241 and No. 1202-C-3228

9 – Surface flow measurement weirs (Baligatan Dam and Dykes)
4 – Surface flow measurement weirs (Magat dam)

Some seepage from the reservoir through the embankments and their foundations is to be expected. The surface weirs measure such seepage. The concern is the possibility of excessive flows through or under the embankments and excessive uplift pressures.

6.3.2 **CONCRETE HEADWORKS STRUCTURE**
- refer to as-built No. AB 1202-G-1020

49 – Uplift measurement piezometers (U)
18 – Torpedo inclinometer Casings (TIC)
5 – Inverted plumblines (I)
6 – Standpipe piezometers
9 – Triangulation targets (C)
1 – Strong motion accelerograph (DGK)
1 – Peak acceleration recorder (on the embankment near the right interface)

The prime concerns relative to the concrete structures pertain to total and differential movements of the structures in any direction. The structures were designed with construction
joint at various locations within the interface structures and the spillway (split piers) and between the various concrete elements to allow for independent movement of elements of these massive structures. Any appreciable movements of these structures would be very significant and examination and analysis of recorded movements should be accomplished without delay.

The uplift measurement piezometers (pressure pipes) provide data on hydrostatic uplift pressure at the point of installation.

The torpedo inclinometers provide information on any horizontal and vertical movement in the rock foundation of the structures.

The inverted plumblines provide information on any relative horizontal movement at various elevations within the concrete structures. Readings of the triangulation targets located at the top of the structures will furnish additional information regarding any vertical and horizontal additional movements.

The strong motion accelerograph at the main dam and the peak acceleration recorder in DGK will provide data on earthquake induced acceleration at and near the structures.

6.3.3 SPILLWAY CHUTE AND FLIP BUCKET
- refer to as-built drawing No. AB 1202-F-C-1072.

(Note: these piezometers were installed along the spillway flip bucket gallery)

These piezometers are intended to indicate any excessive pore pressure which may develop beneath the chute and the flip bucket should the underlying drainage system does not function properly.

6.3.4 FOUNDATION AND DRAINAGE GALLERIES
- refer to as-built drawings Nos. AB 1202-F-C-1069, AB 1202-F-C-1072, AB 1202-F-C-1063 and AB 1202-F-C-1064, and ABDG-13.

45 – standpipe piezometers, includes the three piezometers in the flip bucket area and the six piezometers installed from the headworks gallery at elevation 141.00 meters in to the foundation. In addition there are some drain holes in the low angle shear area which are to be used for taking measurements of piezometric pressure – see drawing No. 1202-F-C-1063.

10 – seepage measurement wiers, three in DGK, two in DGI, and one each in DGL, DGG, and DGEX, one in DGK (S)

2 – flow pipes, one each in DGK (N) and the low angle shear exploratory adit.
1 – Strong motion accelerograph located in drainage gallery K.
The general concern regarding the rock foundation is that it should be kept well-drained and remain in a sound condition. Excessive piezometric pressures or conditions of piping along joints should not be allowed to develop.

Measurements made on the standpipe piezometers will provide information on water pressures in the foundations. Also, in the open-end condition, these piezometers serve to drain the foundation in addition to the drainage provided by the series of drainage holes drilled from the galleries for this purpose.

The seepage measurement weirs and flow pipes provide data on flow quantities from various reaches of the drainage galleries and visual observations provide information on whether the seepage water changes from clear to turbid. Sudden increase in flows or color changes from clear to turbid would indicate problems which require prompt investigation.

A special condition in the foundation is the low angle shear in the vicinity of station 0+231 in drainage gallery K. Drawing AB-DG-13 provides details of the instrumentation installed in the exploratory adit at this location including procedures for measuring and recording. The concern is that movement may occur along this shear zone particularly during an earthquake. The low angle shear zone must be kept as dry as possible and uplift pressures must be kept to a minimum strength. The drain holes in all adits and galleries in the vicinity of this shear zone must be kept clear and free flowing and the seepage from these holes monitored. Also, piezometric pressures must be measured in some drain holes in the vicinity of the low angle shear. The drain holes to be used for this are shown on drawings No. AB 1202-F-C-1063. These data are recorded as for other piezometers.

The strong motion accelerograph in drainage gallery K will provide data on earthquake induced acceleration in the rock foundation.

6.4 INSTRUMENTATION DATA COLLECTION, REDUCTION AND PRESENTATION

6.4.1 GENERAL

There are hundreds of instrument readings which need to be taken at the Magat Dam Complex. These readings, as noted previously, are necessary to evaluate the performance of the structures and the foundation under various loading conditions. The purposes and principles of operation of the numerous types of instrumentation were discussed in the three preceding sections. This Section discusses the data collection frequencies, reading methods, data reduction and methods of compiling and presenting the reduced data. Methods and procedures for analyzing and interpreting the data are discussed in Section 6.5.

The sample forms discussed herein and presented in Volume II of this manual are both field forms and office forms. Forms are designed to separate the readings taken in the field from the reduced and plotted data in the office. Field measurements should be recorded directly on the appropriate form. Once all the necessary instrument readings have been recorded, data reduction can be completed in the office and then the reduced data transcribed.
to summary forms and plotted on graphs. These last two items are discussed in sub-section 6.4.4, DATA PRESENTATION.

The Instrumentation Manual also discusses data collection, reduction and presentation techniques thoroughly. Data collection and reduction discussions contained in sections A, C, and D of that manual are not repeated herein.

In case of conflict between the recommendations contained in this Chapter and the Instrumentation Manual regarding forms, collection frequencies, presentation, etc., THE INSTRUCTIONS CONTAINED IN THIS CHAPTER SHALL PREVAIL AND SHALL BE FOLLOWED.

6.4.2 COLLECTION FREQUENCY

The frequency of instrumentation readings shall be as listed in table 6-1. With respect to the frequency of readings, the following definitions of terms apply:

a. NORMAL CONDITIONS - refer to conditions existing which do not constitute a special event as defined below
b. SPECIAL EVENTS - refer to:
  - any time the rise or fall in the reservoir level is in excess of five (5) meters per day
  - at anytime during the life of the Dam when acceleration of 0.05 G or more is recorded by the seismic instrumentation installed at the site
c. UNTIL NORMALIZED - refers to conditions wherein the change in reading as determined by three successive readings does not vary by more than five percent from the previously established "normal" reading for comparable reservoir levels. In addition, once a special event has occurred, the readings are to be taken in accordance with the frequencies listed in table 6-1 for a minimum of one week. See section 7.5, "UNUSUAL OCCURRENCES OR EMERGENCIES." For other procedures and actions.

6.4.3 DATA COLLECTION AND REDUCTION

a. SAFETY OF PERSONNEL

Collection of data from Magat Instrumentation requires that personnel go into drainage galleries adits, headworks shafts and galleries and spillway chute galleries. The following safety precautions are to be followed in entering any of these, or similar areas:

- At least two people must work together. DO NOT ALLOW ONE PERSON ALONE TO ENTER THESE AREA
- Time of entry and exit shall be logged with the officer on duty.
- Check to see that installed ventilation systems are working properly before entering these areas.
- DO NOT SMOKE OR USE SPARK PRODUCING DEVICES IN THESE AREAS.
- Data collection teams must carry gas detection equipment and flashlights.
- Check for gas accumulations frequently while moving through these areas.
- If detectors indicate presence of gas, leave the facility immediately and report situation to the DRD Manager.

b. PIEZOMETERS

Included in this discussion of piezometers are the uplift pressure pipes installed beneath the head works structures.

(1) Reading procedures. The instrument reading procedures are summarized below. The following references are to the appropriate sections and pages in the Instrumentation Manual.

(a) TELEMAC PIEZOMETERS

See page 4 of Section A, Principles of Operation

(b) SOIL INSTRUMENTS PIEZOMETERS

See page 2 and 3 of Section A, Principles of Operation

(c) PNEUMATIC PIEZOMETERS

In addition to the discussion on Page 6, Section A, Principles of Operation, the operator is cautioned against applying the air pressure rapidly when a hand pump is used. This could "shock" the surrounding soil/water regime and cause inaccurate readings. THEREFORE, DO NOT PUMP AT A RATE IN EXCESS OF SIX STROKES PER MINUTE.

(d) HYDRAULIC PIEZOMETERS

See pages 7, 8, 9 and 10 Section A Principles of Operation

(e) STANPIPE PIEZOMETERS

See pages 10 and 11 of Section A, Principles of Operation

(f) UPLIFT PRESSURE PIPES

These hydraulic pressure measuring devices are not discussed in the Instrumentation Manual. Some of the uplift pipes are connected to permanently wall-mounted Bourdon Gauges and the readings are taken directly in meters of water after ensuring that the drainage outlet from these pipes is closed completely. For others, the method of reading is to attach a bourdon type pressure gauge to the pipe, bleed off entrapped air and read the pressure indicated on the gauge. This same procedure is used for drainage gallery piezometers which are upward sloping or downward sloping peizometers and which are overflowing.
With all these piezometers, it is possible that the reading may drift from an instantaneous high value to a low value. If the reading does not stabilize after 15 minutes, this should be noted on the recording form and the lower reading for this piezometer omitted for this particular reading cycle. Where the pressure on the Bourdon Gauge is recorded as zero, the top cap should be removed from the pipe and the water elevation measured by electrical probe.

(2) Data Forms and Examples

Sample pore pressure recording forms, along with data reduction examples are presented in appendix 4, Volume II of the O & M Manual.

(a) ELECTRICAL VIBRATING WIRE PIEZOMETERS

Calibration charts for the TELEMAC (Pa-) and SIL (Pe-) Piezometers were developed prior to installation of these instruments. Also, standard equations for data reduction are provided in Section D of the Instrumentation Manual. The respective frequency or period reading can be converted directly to meters of water head from the calibration chart or can be calculated using appropriate equations. The actual field readings should be recorded on Form 1 and data reduction and recording for each piezometer done using Form 2.

(b) PNEUMATIC PIEZOMETERS

Pore pressures from these piezometers are recorded in kgf/cm² and converted to meters of water head. Use Form 1 for reading field readings and Form 3 for data reduction and recording for each piezometer.

(c) HYDRAULIC PIEZOMETERS (Pc)

The readings obtained from the Bourdon Gauge must be adjusted to allow for the difference in elevation between the reading point elevation and the installed instrument elevation. (Note that this is a constant which is carried for each series of measurements unless there are changes in the relative elevations of these two points) The reading converted to meters of water head is adjusted by applying the elevation surcharge for the instrument (with appropriate attention to the plus or minus sign of the surcharge). Use form 1 for recording field readings and form 4 for reduction and recording for each piezometer.

(d) STANDPIPE PIEZOMETERS

A sample field data collection form for these piezometers is presented in form 5A. This form should be used for depth to water measurements for standpipe piezometers and TIC installations. Form 5B is a summary form for each piezometer of this category.
Form 6A is the field data form for the uplift pressure pipe readings. This form also should be used for piezometers extending upward and downward and which are overflowing. Form 6B is the reduction and recording summary form by piezometer.

c. **SOIL PRESSURE CELLS**

Reading procedures for these pressure cells are described on page 11 through 13 section A - Principles of Operation of the Instrumentation Manual. Use Form 1 for taking readings and Form 7 for reducing and recording data for each soil pressure cell installation.

d. **TORPEDO INCLINOMETER CASINGS**

Vertical settlements and horizontal displacements along the length of the installed casings are measured from the TIC installations (as noted previously, the TIC installation can be used for obtaining open-well type standpipe piezometer readings). Reading procedures and data reduction are discussed in sections D1 and D-2 of the Instrumentation Manual. Some main points and items of note are:

a. Lateral Displacements: the lateral displacement readings are to be taken at 0.50 meter intervals. A sample field data recording form is presented as form 8. Form 8A is a data reduction form for TICs which terminate in rock. Form 8B is those TICs which do not terminate in rock. Note that calculations for lateral movement are referenced to base line readings each time the data reductions are made.


e. **EXTENSOMETERS**

Reading and data reduction procedures for the SIL extensometer installation including overflow settlement cells are discussed in section D-3 of the Instrumentation Manual. The applicable forms for recording and reducing the data are Forms 10A, 10B, 10C and 10D.

f. **DOUBLE FLUID SETTLEMENT DEVICES**


g. **INVERTED PLUMBINES**

Forms 11A and 11B are to be used for recording and reducing these data.
h. **SURFACE SETTLEMENT AND DEFLECTION MEASUREMENTS**

The instrumentation in this category has been listed previously. They consist of surface measurement points, triangulation points, instrument observation stations and TIC installations. The method of obtaining data is by precise surveys and comparing the data with the base readings. Base readings are to be made for all of the measurement points. Reading procedures following this are discussed in table 6.1. Frequency of readings. The site survey section should develop a simple form for reading and recording the required data referenced to on-site permanent benchmarks.

i. **STRONG MOTION ACCELEROGRAPHS AND PEAK ACCELERATION RECORDERS**

Readings of the data from the accelerograph are made directly from paper graphs or film from the instruments. Peak acceleration readings should be listed on a field of paper and the information transcribed to a summary history form in the office.

j. **FLOW MEASUREMENT WIERS**

Form 12 is to be used for recording field readings for drainage gallery weirs and calculating flows. Form 12A is for use in summarizing these data. Similar forms shall be prepared for the surface flow measurement weirs.

k. **FLOWS FROM GALLERY DRAIN HOLES**

Form 13 is for use in recording flows from the drain holes and flow measurement pipes and for reducing the data. Form 13A is for maintaining a record of flow for each drain hole. In taking measurements from the drain holes a container of appropriate volume should be used such that time required to fill the container is about 15 seconds. The size of the container used for each drain must be recorded on the form.

The methods of obtaining data is to measure the time required to fill container of known volume.

l. **LOW ANGLE SHEAR ZONE MEASUREMENTS AND CALCULATIONS**

Forms for recording data and calculating movements of the instrumentation installed in the exploratory adit of the low angle shear in drainage gallery K are shown on forms 14A and form 14B.

m. **SURVEY ELEVATIONS**

Many of the instrument installations (including reading points) such as piezometers, stress cells, TICs DFSD's and surface measurement points are
sensitive to absolute elevation changes. Although such changes can in general be ignored for pressure measuring devices such as piezometers and stress cells, they must be considered for movement measurements such as those by TICs DFSD loops and surface measurement points. While it can be assumed that the elevation points on the concrete headworks will remain fixed with time as the concrete structures are founded on rock, TIC tops and other movement reading points founded on the embankments will settle with time. Therefore every effort must be made in those cases to work with the most accurate elevation data possible. The elevation change of instrument reading points and of instrument houses must be surveyed for each set of readings until there are no longer any appreciable changes in elevation. "Appreciable" is here defined to mean a change in elevation less than or equal to the accuracy of the most sensitive instrument read.

6.4.4 DATA PRESENTATION

This subsection covers the compilation of data into a readily understandable form and also addresses methods for graphical presentation of data to facilitate an evaluation of the overall dam performance or an evaluation of a particular dam feature. The following paragraphs address summary data forms and graphical methods of the data presentation:

a. SUMMARY FORMS

Data of a similar nature on a dam feature basis should be summarized on one sheet to facilitate comparison and evaluation of historical trends. Listed below are guidelines with references to example forms outlining the recommended dam feature summary basis where applicable.

(1) Piezometers

The data from all types of piezometers should be summarized on separate sheets for each of the following dam features:

- Spillway and Headworks
- Magat Dam Section MA
- Magat Dam Section MB
- Magat Dam Right Abutment
- Baligatan Dykes
- Baligatan Dam and Dykes Sections DB, DA, BA, and BD
- Left and right interfaces (in combination with stress cells)
- Drainage Galleries

Each project feature's summary sheet should include:

- Piezometer designation
- Installed tip elevation and offset from centerline
- Elevation of piezometric head
- Reservoir level at time of reading
- Tailwater level at time of reading
- Any pertinent notes or comments on observations

Form 15 is an example Piezometer Summary Form for Section MA of the Magat Dam.

(2) Soil Pressure Cells

Form 16 is an example form of recording soil pressure cell and companion piezometer data.

(3) Torpedo Inclinometer Casings

Typically, three types of data are obtained from each TIC installation. These are water level measurements at the point of installation of each casing. Also, displacement at the top of each exposed TIC casing should be monitored as a part of the surface deflection measurement system. Water levels are summarized on the appropriate piezometer summary forms. Form 17 is a TIC lateral movement Summary Form. Form 18 is a TIC vertical settlement summary form. The data for these summary forms are taken directly from the field and in both cases data are referenced to initial observations and readings.

Summaries of external movements are discussed in subsection (7)

(4) Extensometers

An example extensometer summary sheet is presented in Form 19. The data for this form are transcribed directly from the field form.

(5) DFSD Loops

Procedures for summarizing DFSD Loop data are addressed in the Instrumentation Manual.

(6) Inverted Plumblines

The readings for all five of these installations are summarized on one form. An example is presented in Form 20.
(7) Surface measurement points

It is not easy to summarize in tabular form the measured deflections or settlements of the many surface measurements points. The data should be summarized by tabulating original elevations and locations then in successive columns record data for the following readings:

- the new SMP elevation
- the new SMP location
- the settlement of the SMP in centimeters
- the direction and amount of lateral movement in millimeters

A sample form for summarizing these data is not presented herein.

(8) Accelerograph and Peak Acceleration Recorders

A running summary of measured earthquake induced accelerations should be prepared. All these records should be filed together.

(9) Flow Measurements

Weir and pipe flow measurement are summarized on Form 12A. Drain hole measurements are summarized on Form 13A.

(10) Low angle shear instrumentation

The data as recorded on the field forms provide an adequate summary. These forms should be filed together.

b. GRAPHICAL PRESENTATION

Data tabulated on summary Forms should be presented graphically in such manner that historical data trends and project feature performance can be reviewed and interpreted readily. Graphical data presentation methods along with example plot as appropriate are discussed below. The example plots discussed are those required to show historical trends. However, in addition to these plots which will present the data dating back to initial recordings, year by year plots should be made on separate sheets with appropriate adjusted scales.

(1) Piezometers

All piezometer data including that from foundation piezometers should be plotted on standard size drawing paper with the vertical axis designated for piezometric level and the horizontal axis designated for time. The vertical scale should be such that, in general, all expected piezometric elevation readings/determinations for the particular section can be plotted on the chart. An example plot is presented on Form 21. The plots should show
graphically the reservoir and tailwater readings. The following reference information should be included on each plot:

- summary of piezometer tip elevation
- an inset drawing showing the instrumented section with locations of the piezometers and the centerline of the grout curtain
- key to terms and symbols
- list of as-built reference drawings

Piezometer groupings for the plots as described above should be as follows:

- left and right interface piezometers (one for each interface)
- main embankment section MA piezometers
- main embankment section MB piezometers
- headworks uplift pipes and spillway chute piezometers
- Magat dam foundation piezometers (inset should show plan locations)
- Baligatan dyke section DA and DB piezometers
- Baligatan dam and dykes standpipe piezometers (inset should show plan locations)

(2) Soil Pressure Cells

Two graphs of pressure cell readings versus time, one for each interface, are required for presentation of data from these instruments. The following should be included with each graph:

- an inset drawing showing instrumental location relative to interface wall and dam axis.
- a matched plot of reservoir elevations at time of readings

A sample graph is shown on Form 22.

(3) TIC Data

Three plots of TIC data are to be maintained: two plots of lateral deflections vs. elevation (one for the channel A and one for the Channel B) and another plot for cumulative coupling settlements (vertical movements) at selected elevations vs. time. These plots should be grouped by sections (such as section MA) and on one drawing for each plot.

- channel A
- channel B
- Settlements

Example plots are shown on Forms 23 and 24
Settlement readings do not need to be plotted for every coupling. They should be done for couplings at 5 to 10 m intervals (depending on overall length of TIC) and plotted against time.

(4) Extensometer Data

These should be plotted as shown on Form 25.

(5) Double Fluid Settlement Devices

The double fluid settlement device data from the readings are summarized by tracing successive loop runs on a master graph. The procedure is described in the Instrumentation Manual. A chart should then be prepared for each of the following sections illustrating the settlement progress at each loop location:

- Main dam Section, MA
- Main dam Section, MB
- Longitudinal section from the right interface at larger scale showing movements close to the concrete structure (short DFSD loops)
- Baligatan dam section, BD

These charts should show settlement progress with time as a continuous plot throughout the entire length of each loop. At the right interface, a continuous plot should show to a distance of 10 meters outside the wall for all zones.

(6) Inverted Plumblines

A form for graphical presentation of these data is shown on Form 26. Note that all five installations should be plotted on one sheet. Each graph should show upstream – downstream and left bank-right bank tilts at the elevation of each of the reading points.

(7) Surface Movements

There is no easy way graphically to present the data for all of the surface settlement and deflection measurement points. As shown on Table 6.1, periodic readings are to be taken for the crest points only unless a difference in successive readings is 2 centimeters or more. In such event, readings for the points on the slopes in the vicinity of the crest point involved should then be taken.

Form 27 is use in plotting data for crest measurement points. The plots are to be made on a full size drawing. Data for several dates are to be plotted on the same drawing to facilitate comparison. This one plot is to be divided into portion for the Baligatan dam and a portion for the Magat dam, headworks and north dam.

Reading for slopes point is to be recorded and filed without making a plot unless movement of significance occurs.
(8) Strong Motion Accelerograph and peak acceleration recorders

The accelerometers and the accelerograph produce graphical plots. Peak acceleration readings are summarized on a record sheet. Further graphical presentation is not appropriate. The records should be filed together.

(9) Flow measurements

Flow measurements are to be plotted on Form 28. One drawing should be made for the Magat dam, headworks and north dam showing plots for MWE-1, MW-1, and MWL-1 and for the surface weirs such as WRA1 and WLA1.

Another drawing should be made giving results for each weir at the Baligatan dam and dykes.

Rainfall and reservoir level data must be included on both drawings.

(10) Low angle shear instrumentation

Movement data are not suited to graphical presentation. A tabular summary will suffice.

6.5 INSTRUMENTATION DATA ANALYSIS AND INTERPRETATION

6.5.1 GENERAL

This section discusses data analysis and interpretation in general terms and covers actions which must be taken by the site personnel. More detailed analysis and interpretation will be performed by National Irrigation Administration Central Office or Consultant/Scientist.

The following matters should be kept in mind when reviewing the large number of data summaries and plots that will be accumulated at Magat:

- Are the instrumentation data compatible with any associated visual observations?
- Historical trends instrument for similar conditions such as a full reservoir are usually more significant than absolute values.
- Data from one instrument (and particularly an unusual reading) must be considered in the light of information from other instruments of similar or related type in the vicinity.
- Unusual data should be checked, first by ensuring that the data reduction is correct and, if so, then by taking another reading immediately.
- All the data for a particular portion of the complex (such as Magat dam section (MA) must be considered together. This can involve embankment pore
pressures, embankment deflections and settlements, foundation piezometric heads and foundation drainage and seepage flow measurements.

- The more complex the instruments, the more care must be exercised in taking readings and in data reduction.
- All movement measuring devices such as settlement and lateral movement devices, respond relatively quickly to changes in loading conditions. However, there are lag times associated with other instruments, especially piezometers, where it takes varying lengths of time for changes in reservoir levels to be reflected within the embankments and the foundations.
- After reviewing instrumentation data in accordance with the steps listed previously, if there is any indication that an abnormal condition is developing, the DRD Manager must be notified immediately. Any doubts should be resolved in favor of notifying the DRD Manager.

6.5.2 ANALYSIS AND INTERPRETATION BY INSTRUMENTATION TYPE

a. PIEZOMETERS

Evaluation depends on consideration of type and location and should generally be based on historical trends rather than specific values for each instrument.

(1) embankment piezometers

There should be a reduction in piezometric head as water seeps through embankment zones. In relative terms the piezometric head should be:

- upstream of the embankment core (zone m1) the head should be equal to, or nearly equal to, the elevation of the reservoir
- through core, there should be a substantial drop in head across core
- Downstream of the core, there are fill zones which serve as chimney drains. These connect to horizontal drains which are constructed of similar materials. These zones were designed to intercept and carry off water seeping through the core without any local pending. Thus the piezometric head being measured higher than the tailwater level is higher than the piezometer tip. When the tailwater level is lower than the tip, the piezometers downstream of the core should indicate very nearly zero water pressures.

Piezometer data at instrumented embankment sections should be evaluated considering the above and the following:

(a) Are the data reasonable? If not, check data reduction for errors. If there are no errors, re-read the instrument immediately. Meanwhile proceed with step (b).
(b) What is the relative response time for the instrument and has it stabilized for the loading conditions? If not, does the reading and the change in reading fit the historical data? If similar, proceed to step (c). If dissimilar, do other instruments show the same trend? If so, notify the DRD Manager. If the instrument reading
has stabilized, has the time to stabilize changed significantly for historical trend? If so, notify the DRD Manager.

(c) Are there any visible signs or other related instrument readings which indicate the area in question may be under distress? If so, notify the DRD Manager.

(d) Are there piezometer readings (other than those upstream of the core) which change at the same rate as the reservoir fluctuation? This would indicate direct communications between the reservoir and the instruments location. When verified, notify the DRD Manager.

(e) Piezometer readings which historically have exhibited a discernible lag in response show appreciably quicker responsive time. This should be reported immediately to the DRD Manager.

(2) **Foundation piezometers**

These are subject to the same general considerations and comments as embankment piezometers given as follows:

(a) the piezometric head should drop gradually from the upstream to the downstream side of the core contact. Foundation piezometers located at or near the toe of the embankments should indicate piezometric head very close to or even below the tailwater level.

(b) Downstream piezometers may or may not respond quickly to reservoir level changes.

(c) Historical trends in head relative to reservoir levels and response times must be established. If unexplained changes in these occur, notify the DRD Manager.

(d) Headworks piezometer

Piezometric measurements near the upstream edge of the headworks should be close to the reservoir levels. Piezometric elevations should decrease with increasing distances from upstream to downstream. Historical trends must be established and current readings compared with these trends, if verified readings differ from the historical reading, notify the DRD Manager.

b. **SOIL PRESSURE CELLS**

As these cells are located in the critical interface of the embankments and the concrete structures and because they are known not to record consistently the correct magnitude of Stresses, it is particularly important to consider piezometric, extensometer and settlement data close to the interface with the stress cell data.

If there is sudden decrease in the reading of any stress cell:
- check other stress cells at the same elevation to see if the change is about the same
- if not check calculations and re-read immediately
- Do the companion piezometers on the interface and in the embankment show a marked increase in pore pressure? If so, notify the DRD Manager
- Does the companion stream cell show similar changes? That is markedly less stress and a marked increase in pore pressure? If so, notify the DRD Manager.
- Are there visible signs in the area, such as changes in seepage or surface settlements indicating the development of embankment cracking or separation of the embankment from the interface wall? If so notify the DRD Manager.

c. **TORPEDO INCLINOMETER CASINGS**

Only internal horizontal movement and vertical settlements are discussed herein. Top of casing movements are included with the discussion of surface deflection measurements.

(a) **Settlements**

Most of the total settlement during the life of the structures will have occurred during the construction and initial impoundment. This has been measured and plotted. With time, additional settlements should be small and the rates of settlement in various zones of the embankment should decrease, eventually becoming virtually zero. If this trend changes at any time during the life of the project, notify the DRD Manager. Any changes in the settlement patterns most likely will occur suddenly after on-site earthquake induced accelerations.

The rock foundations are assumed to be incompressible. If movements of more than one centimeter are measured in the TICs in the concrete headworks, further investigation such as taking readings of the low angle shear instrumentation and the inverted pendulums should be made to determine the likely cause of such movements.

(b) **Horizontal movements**

Again, most of these movements should have occurred during construction and initial impoundment. Comments on settlement also apply to horizontal movements.

d. **EXTENSOMETER DATA**

Extensometer data must be considered in relation to other horizontal movement data and other instrumentation data in the vicinity. After initial reservoir filling, the lateral movements in the interface area should in general be very minor and the rates should decrease with time to virtually zero, except possibly following an earthquake. Increases each time indicate a potential problem which must be analyzed considering all instrumentation data. If this occurs, notify the DRD Manager.

e. **DFSD Loops**

The discussion above for TIC settlement analysis is also applicable to DFSD loop data. In addition, the DFSD loops provide information on differential settlements
between adjacent zones of different materials within the embankments. Suspect data should be cross-checked with settlements from TICs and compared with historical trends for determination of development of abnormal conditions. If this is apparent, notify the DRD Manager.

f. Inverted plumblines

The data for upstream/downstream strains should be analyzed relative to trends for comparable reservoir levels. If readings deviate from historical ranges, notify the DRD Manager.

After initial impoundment, the concrete structures should not move parallel to the dam axis. An exception to this could be due to earthquake induced foundation accelerations. If any movements in this direction are measured notify the DRD Manager.

g. Surface settlement and deflection measurements

Any movements recorded should be small after initial impoundment and should decrease with time to virtually zero. If any changes from the previous reading of a centimeter occur, a cross check with other instrumentation data should be made for indications of abnormal behavior. If there is abnormal behavior condition indicated, the DRD Manager should be notified immediately.

h. Flow measurement devices

As for other data, historical trends should be established. Analysis is then carried out considering these trends.

(1) External (surface) seepage weirs

The plots of quantity measurements for each weir relative to reservoir levels and local rainfall establish the historical trends. Readings must be taken at the appropriate times to separate out the effect of rain. An increase in quantity (not related to local rainfall) in excess of 10% as compared to the historical flow quantity for the particular reservoir level must be reported to the DRD Manager. If this increase occurs, or the discharge changes from clear to turbid, institute "special event" frequency of readings per Table 6.1.

(2) Foundation weirs

The same principles are discussed for external weirs apply. Plots of quantity, reservoir levels and local rainfall with time are to be made for each weir and each flow pipe. All the drainage gallery discharges (particularly DGG and DGK) are affected by ground water from the adjacent side hills. This means that the data must be reviewed keeping in mind recent local rainfall.
Flow increase of 10% or more for similar reservoir levels should be investigated further and reported to the DRD Manager. Also, proceed with special events frequency of readings.

(3) foundation drain holes

Samples of water from several drain holes should be collected and sealed as base samples for future reference. Samples should be taken from each of the following locations: DGG, DGE, DGM, DGI, and DGK.

Again, historical trends must be established for various reservoir levels. If an individual drain hole shows an increase in flow of more than 10% for a similar reservoir level, a sample of water should be taken and the sediment contents compared with that of the base sample for the drainage gallery involved. Report the situation to the DRD Manager.

Drain holes showing a tendency toward reduced flows under similar conditions must be checked to determine if they need cleaning or re-drilling. Report the situation to DRD Manager.

i. Low angle shear zone instrumentation

Any movement of the low angle shear zone must be reported to the DRD Manager immediately. In addition, other instrumentation data from the vicinity must be reviewed and the "special events" frequency of readings initiated. Visual checks for any movement of structures must be made immediately.

6.6 INSTRUMENTATION REPORTS

6.6.1 MONTHLY REPORTS

As stated in Chapter 2, the DRD Manager shall submit a monthly instrumentation report to the National Irrigation Administration Central Office. The report is to arrive at the Central Office by the 15th of the month following the month being reported.

The instrumentation report should contain the following:

a. Completed summary forms

- piezometers data by section – Form No. 15
- soil pressure cells and companion peizometers data for the interface areas – Form no. 16
- TIC data for each TIC – Forms Nos. 17 and 18
- Extensometers and overflow settlement cell data for the two interface areas – Form no. 19
- Inverted plumblines – Form no. 20
- Flow measurements for drainage gallery weirs and surface weir – Form no. 12A
- Flow from drain holes for each drainage gallery – Form No. 13A
- The running summary record of earthquake indicating accelerations

b. **Completed graphical presentation forms**

- piezometer data by section – Forms no. 21
- total stress call data for each interface Form no. 22
- TIC lateral movement data for each channel and settlement data by section – Form no. 23 and 24
- Extensometer data for each interface – Form no. 25
- DFSD master charts showing successive settlements for each section
- Inverted plumbline data-Form no. 26
- Surface measurement points data – Form no. 27
- Flow measurement data – Form no. 28

c. **Instrumentation analysis and interpretation**

Instrumentation analysis and interpretation shall be prepared by the Magat dam complex personnel including summary comments on visual surveillance of the project features and the reservoir.

6.6.2 **Annual report**

In addition to the monthly reports, the DRD Manager shall submit a yearly instrumentation report to the Nation Irrigation Administration central office. This report should summarize the previous year's event with the maximum possible use of graphical presentations. The yearly report will be carefully studied by safety evaluation personnel prior to their formal safety inspections.
CHAPTER 7
INSPECTION AND MAINTENANCE OF STRUCTURES

7.1 GENERAL

7.1.1 PURPOSE

The water stored behind the Magat Dam has tremendous potential energy which if not properly managed will constitute a hazard to life and property located downstream. Major dam failures have occurred in recent years in countries around the world and many of these failures resulted from inadequate and improper surveillance and maintenance procedures which had not been established. In cases where there are established procedures, these were not carried out effectively resulting to such disasters. Aware of the importance of established procedures and effective monitoring and implementation of dam regulation procedures, the National Irrigation Administration made it a policy that risks associated with the storage of water behind its dams be totally eliminated if not reduced to a minimum.

The primary means of accomplishing risk reduction for the Magat Dam Complex is by effectively carrying out the operation, maintenance, inspection, repair and instrumentation procedures described in detail in this Manual as well as those in other flood manuals prepared by PAGASA. It is very important for the integrity and safety of the Magat Dam Complex that all facilities, instruments and appurtenant structures be kept in like-new condition.

To ensure that all of the above-mentioned actions and measures are being carried out in proper order, the National Irrigation Administration conducts maintenance inspections each year under the supervision of senior officers. In addition to the maintenance inspections, NIA also regularly conducts safety evaluations of its dams (please see Section 7.2). It has likewise instituted a regular training operation and maintenance program. It is strongly recommended also that key personnel should not be withdrawn or transferred until a well trained replacement is ready to take over the job.

7.1.2 SCOPE

The scope of this chapter pertains to specific actions and procedures to ensure that the dams and its appurtenant structures are regularly inspected and maintained in good condition. Those generally inspected are the actions and procedures needed to be taken on an urgent basis after the occurrence of a major unusual or emergency event as described in detail in Section 7.5.

It is not the intent of this Manual to discuss required repair/reconstruction procedures in detail as there are many possibilities and contingencies involved. The choice of major remedial measures and repairs to ensure safe performance of specific structures will have to be determined based upon the specific prevailing condition by the Magat Dam Complex operation and maintenance authorities in coordination with the NIA Central Office.
7.2 DAM SAFETY EVALUATIONS

7.2.1 PRINCIPLES AND CONCEPTS

The purpose of dam safety evaluations is to review the performance of the various structures and to assess the operation and maintenance practices being followed in order to judge the structural and operational safety of the dam. It is important that thorough and complete evaluations of the structures and their operation and performance be done at regular intervals.

In conducting these periodic evaluations, the principles and procedures discussed in the DAM SAFETY PROGRAM manual of the National Irrigation Administration, be followed. The details contained in that document are no longer presented here but the discussions and general observations discussed in this Chapter are based on that document.

7.2.2 FREQUENCY OF EVALUATIONS

Prior to 1987, the dam safety evaluation of the Magat Dam Complex was done annually. Thereafter, however, inspections which should be done at five year interval, were no longer strictly followed because of the disbandment of the Dam Safety Group based at the NIA Central Office.

It is likewise imperative that special dam safety evaluations be conducted immediately after the occurrence of any of the following:

- The first earthquake induced ground acceleration at the site of a magnitude of 0.05 gravity or greater, and then after each earthquake induced ground acceleration of 0.10 gravity or more.
- Floods which produce spillway discharge in excess of 20,000 cubic meters per second.
- Development of any other condition (such as major settlement or major leakage) which indicates that the integrity of the project structures may be threatened.

A visual inspection of the Magat Dam Complex shall be accomplished by the dam operation and maintenance staff on a regular basis with a frequency of at least twice a year. A check list for recording the results of these formal inspections must be prepared (included as Appendix 3, Volume 2 of this Manual). A comprehensive report of the visual inspection shall be submitted with the next monthly Operations and Maintenance Report.

In addition to the scheduled visual inspections, all operation and maintenance personnel should be trained and instructed to look for signs of deterioration or problems while performing their normal duties. As appropriate, travel routes should be established so that these personnel pass close to the critical project elements described herein.
7.2.3 DAM SAFETY EVALUATION PROCEDURES

The dam safety evaluation shall be conducted following the procedures given in the National Irrigation Administration’s DAM SAFETY PROGRAM MANUAL. They are briefly summarized below:

a. **PRE-INSPECTION PROCEDURES**
   The safety evaluation begins with a review of available data (hydrology, design criteria, instrumentation, earthquake events, reservoir operation, monthly reports, etc.) before commencing field studies. An abbreviated and convenient compilation of much of the needed information and data is assembled in the Magat Dam Complex Data Book which is on file in the Dam Safety Evaluation Group Office of the Central Office, Quezon City (unfortunately, the members of this group are no longer with the NIA at present but it is imperative that NIA revives the group to continue the important and delicate task of monitoring and evaluating the performance of NIA-operated dams in the country). The Data Book shall be updated prior to each safety evaluation. The DRD concerned Staff shall forward such data and information as is required for the Data Book, e.g. unusual occurrences or emergencies, repairs and modifications, etc.

b. **FIELD INSPECTION PROCEDURES**
   In the field, operation and maintenance records shall be checked, followed by physical check of all structures and equipment. In addition, the 1987 safety evaluation, or that following a spillway release in excess of 20,000 cubic meters per second, shall include review, and up-date if needed, of the reservoir flood routing calculations.

c. **REPORTS AND FOLLOW-UP ACTIONS**
   In the absence of the Dam Safety Evaluation Group, concerned DRD Section shall prepare a detailed report for review of the NIA CO for them to recommend remedial measures.

7.2.4 SAFETY EVALUATION TEAM

Members shall be experienced in their professional fields and should have had extensive experience in the design, construction and operation of large dams. Further, they should have the appropriate desires, abilities and personal attributes for making detailed observations and performing thorough, highly professional analyses and judgments regarding dam safety considerations.

The examination team should be comprised of an appropriate number of professionals whose experience covers the following areas: hydrology and hydraulics; geotechnical engineering (including dam instrumentation expertise); design and maintenance of structures; and mechanical-electrical design operation and maintenance. Experts in other fields may be assigned to the team as warranted by the purpose and needs of the inspection.
The examination team preferably should include personnel who had been involved in 
the design and construction supervision of the complex, but should also include at least one 
member who was not involved in the project.

7.3 NORMAL INSPECTIONS AND MAINTENANCE OF STRUCTURES

Visual inspections shall be made following the principles and procedures given in the 
latest version of the Dam Safety Program Manual. Some detailed instructions specifically for 
the Magat Dam Complex are given thereafter in Section 7.5.

7.3.1 SAFETY OF PERSONNEL

Operation and maintenance activities as well as visual inspections involved in going into 
tunnels, shafts, drainage galleries and adits must be performed with extreme precaution. The 
following safety precautions are to be followed in entering any of these:

- At least two people must work together. DO NOT ALLOW ONE PERSON ALONE 
  TO ENTER THESE AREAS.
- DO NOT SMOKE OR USE ANY SPARK PRODUCING DEVICES IN THESE 
  AREAS.
- Check to see that the installed ventilation system is working properly before entering 
  these areas, (Applies to all galleries and the Baligatan Outlet Works Concrete Tunnel).
- Inspection teams must carry gas detection equipment, has masks and flashlights.
- Check for gas accumulations frequently while moving through the tunnels, galleries 
  and adits.
- IF THE DETECTORS INDICATE PRESENCE OF GAS, LEAVE THE AREA 
  IMMEDIATELY and report the situation to the DRD Manager.

7.3.2 WARNING SIGNS OF POTENTIAL DANGER TO DAM SAFETY

a. EMBANKMENTS

From the standpoint of the safety and integrity of the dams and embankments, 
special attention should be given by operation, maintenance and inspection 
personnel to the following signs of potential danger to the structures.

- Increasing seepage or leakage through the embankments.
- Increasing seepage or leakage from the dam foundation, through the 
  abutments, or in the interface zones at concrete structures.
- Increasing seepage around the periphery of the diversion tunnels and 
  the Baligatan Outlet Works.
- Change from a clear to a turbid appearance of seepage or leakage 
  which is not directly related to drilling and grouting, or similar 
  activities, in the vicinity.
- Unusual increases in pore pressures within embankments or in the 
  foundations.
Abnormal settlement or displacement of the embankment fill material, including the development of any slumps, cracks or seams.

- Heavy erosion of embankment slopes resulting from reservoir wave action or surface run-off from rainstorms.
- Any movements in the embankments foundations

b. **CONCRETE STRUCTURES**

- Increasing seepage or leakage in the foundations.
- Cracking of structural elements
- Significant settlement, movement or displacement of structural elements.
- Seepage or leakage through cracks and joints.
- Deterioration of concrete surfaces as a result of cavitation, vibration, or impact from high velocity flows carrying abrasive materials.
- Surface cracking or spalling of concrete due to adverse chemical reactions or to leaching.
- Any movement in the foundations of the concrete structures.
- Erosion in the plunge pool area.

### 7.3.3 EMBANKMENTS

Measures to maintain the integrity of the dams and dykes start with visual inspection and are supplemented by the instrumentation surveillance actions covered in Chapter 6. The following are specific problem areas and notes regarding inspection and maintenance with indicated activities to be undertaken:

a. **SETTLEMENT/DISPLACEMENT**

Some settlement is normal in new embankments sometimes extending into a considerable period after completion of dam construction and initial reservoir filling, however, differential settlements, as evidenced by open cracks or seams, can be serious and require prompt evaluation and corrective measures.

- Check for any evidence of settlement/displacement along the crest by observing the horizontal and vertical alignment of the roadway, the roadway guardrails and other lineaments.
- Check upstream and downstream faces by looking for any changes in the alignment of the riprap slope protections.
- Cross check any observed abnormalities with the results obtained from the dam instrumentation.
- Report significant settlement/displacement immediately to the DRD Manager for evaluation and determination of corrective action required. The DRD Manager shall report this to the MARIOS OM who will in turn report the same to NIA Office, Quezon City, for further evaluation.
b. **SEEPAGE/LEAKAGE**

Seepage is differentiated from leakage in the context used herein. Seepage refers to the movement of water through the embankments without displacement or movement of the embankment material, whereas leakage refers to the passage of water through embankment cracks or fissures with sufficient velocity to cause movement of embankment particles or to cause piping action. Uniform seepage after establishment of steady state conditions is to be expected. However, a sudden increase in seepage and any leakage are serious matters which should be analyzed in depth promptly.

- Seepage and leakage in the embankments foundations are checked by taking readings of the various flow measurement weirs installed in the drainage galleries.
- For the main dam and dykes, downstream to drainage systems are installed to collect flows and channel them to measuring weirs. The locations of the weirs are shown on Drawings AB 1202-C-3228 and AB 1202-C2-3241. The Instrumentation Section shall take measurements from these weirs and correlate them with reservoir elevations. At locations where permanent measuring weirs do not exist, flow quantities should be measured by temporary weirs or other expedient methods.
- Visually inspect all portions of embankments' downstream faces, with particular attention to the toe and downstream area for development of or increased flows from springs, seeps, or bogs. Measure and record any flows discovered. Be alert for any changes in color from clear to turbid. Correlate flow measurements with reservoir elevation.
- Check, measure, observe for color, and record any seepage along the contact faces between the main embankment and the concrete structure and the north main embankment and the concrete structure. Check for any flows at all contacts between dams and dykes and abutments. Measure and continue to observe for any evidence of movement of embankment materials and the pattern of such.
- During periods of low reservoir levels, check all exposed portions of abutments and upstream embankment faces for sinks, seepage holes, slides or sloughs. Check for air bubbles at the water surface on near damp patches on the slopes.

c. **SLOPES AND CREST MAINTENANCE**

The upstream and downstream faces of canal embankments, dams and dykes of the Magat Dam Complex has been protected with heavy rock. For dam safety purpose it is important to maintain these surfaces and the crest in the as-constructed condition, the most important element of which is the prevention of erosion damage from surface runoff. However, other forms of damage (such
as reservoir wave action) are possible. Regardless of the cause, the slopes and crest should be repaired to like new-condition as soon as possible.

- Inspect both faces and the crest of dams and dykes for evidence of damage, particularly erosion damage. Particular attention should be paid to the size of the grains. (M7-12)
- Repair any discovered erosion damage as soon as practicable.
- Inspect for vegetation on all embankments and for distance of 5 meters downstream of embankments downs. Remove the vegetation and its roots as part of routine maintenance. This serves two purposes: first it will provide for ease of inspection to identify new seeps or bogs; and second it will prevent development of seepage paths caused by the root of large trees and plants.

7.3.4 CUT SLOPES

There are cut slopes at the following locations of the Magat Dam Complex:

- Along both sides of the spillway chute, the plunge pool and the outlet channel.
- Along both sides of the penstock area, the Magat Hydroelectric Plant and the tailrace channel.
- Along both sides of the diversion tunnels, approach channel and outlet channel.
- Along both sides of the Baligatan Outlet Works outlet channel.

All of these cut slopes must be maintained in a safe condition except those of the diversion tunnel approach which are now generally submerged. Following are minimum actions regarding the cut slopes:

- Inspect for cracks, minor slides and any other evidence of potentially dangerous slides.
- If potential slide or an actual slide is identified, report the matter to the Chief DRD Manager who will in turn report immediately to the MARIIS OM for an engineering evaluation and determination of the appropriate corrective action(s) including necessity for removal of slide materials.

7.3.5 CONCRETE STRUCTURES

This section covers actions which, in general, are applicable to all concrete structures of the Magat Dam Complex. As mentioned previously, actions to be taken are based on visual inspections. Other indications of potential danger to concrete structures may come from analysis of the data collected from the dam instrumentation. Of particular concern are the occurrence of cracks and of surface deterioration.

Nominal hairline cracking due to shrinkage or temperature changes should always be expected. This normal cracking does not impair the integrity of the structure, however, offsets, openings or considerable leakage occurring at cracks or
joints are serious and require close monitoring and immediate remedial measures are necessary.

The development of significant cracks in concrete structures generally is indicative of movement or displacement of the structures on their foundation. For Magat, in nearly all instances this can be verified by analysis of the instrumentation data.

Surface deterioration can be caused by faulty construction, weathering, scouring, erosion, cavitation, vibration and adverse chemical reactions. Scouring, erosion or cavitation damages are potentially serious problems in high velocity waterways, such as the spillway chutes and the Baligatan Outlet Works. In the event that repair has to be done due to surface deterioration, the procedures as discussed in full in the U.S. Bureau of Reclamation Concrete Manual is a good reference.

The following are specific actions to be taken with respect to the Magat concrete structures:

- Inspect for surface deterioration and possibilities of structural failure, particularly on all structures that are exposed to rapidly flowing water. Emphasis must be given to joints between vibrating parts and their foundations and structural construction joints that are subject to vibration. When deterioration is significant, repair shall be made as soon as practicable.
- Visually inspect for evidence of movement of structures. The movement may or may not be associated with the development of cracks. If movement is suspected, make special instrumentation cross-checks, including a survey of surface settlement and displacement benchmarks. In case of differential settlements or significant change in settlements or displacements (after initial reservoir filling) report the matter immediately to the DRD Manager.
- Inspect for leaks in construction joints and contraction joints. Following are the locations of major joints in the concrete headworks structure:

  1. In the right interface structure (five joints)
  2. Between the right interface structure and the power intake structure
  3. In the power intake structure
  4. Between the power intake structure and the orifice spillway
  5. Between the left orifice pier and the right exterior ogee pier
  6. In the piers of the gated ogee spillway (split piers)
  7. Between the spillway and the left interface structure
  8. In the left interface structure (three joints)
  9. Throughout the spillway chute around each chute floor block and between the chute floor and the foundation of the training walls.

Note: All of these joints were constructed with water stops and/or seals. (Asphalt block seals are installed between the water stops in the interface, power intake and spillway concrete structures).
Monitor leaks. Minor seepage through these joints is to be expected. If considerable leakage occurs, further examination to determine cause is required. Leakage may be due to defective seals, or more importantly, may be due to differential movements.

If leakage is due to movement of structures, the NIA Central Office should arrange for examination and analysis of the situation by competent/expert Consultants.

After examination and analysis of leakage in the interface and spillway concrete structures, it may be necessary to apply steam for melting installed asphalt block seal to re-seal the joints.

At low reservoir stages, inspect structures, or portions of structures that are normally submerged in the reservoir (this applies primarily to the spillway, power intake interface structures) and undertake the required repair as soon as practicable. Report evidence of major problems to NIA Central Office for action.

7.3.6 MAGAT SPILLWAY, SPILLWAY CHUTE, FLIP BUCKETS AND SPILLWAY APPROACH CHANNEL

The proper operation of the spillway system to pass the design discharge capacity of 30,600 cubic meters per second is the most important aspect of Magat Dam safety. Overtopping of the rock and earthfill dams and dykes could result in a catastrophic failure resulting in loss of many human lives and extreme property damage. THEREFORE, PAINSTAKING MAINTENANCE, OPERATION AND SURVEILLANCE OF THE SPILLWAY SYSTEM IS ESSENTIAL. Inspection and maintenance of the spillway and spillway approach channels shall include the following specific actions:

1. Inspect the spillway approach channel and keep it clear of obstructions. Remove any accumulated debris and driftwood from the channel on a regular basis. THIS MUST BE DONE WITH THE SPILLWAY GATES CLOSED.
2. In case of slides into the approach channel or accumulation of silt blocking the channel, remove the obstruction as soon as possible.
3. Complete all repairs to the accessible part of the spillway system prior to the beginning of each annual rainy season.

The spillway ogee and the chute are divided into parts by the seven gates bays and the chute are divided into parts by the seven gated bays and the chute intermediate training wall so that elements of the system can be isolated for making repairs.

Similarly, the spillway ogee structure is divided into seven separate blocks to allow for movement between the blocks with the intent of reducing the possibility of jamming of the spillway radial gates.
o Inspect for movement or displacement of each of the spillway ogee blocks. Report any movement or displacement to the DRD Manager.

o Inspect the seepage past the waterstops in the vertical access shafts at each joint in the ogee bays. If seepage increases with relatively constant reservoir level, investigate to determine cause. Check with instrumentation data for determination or movement of spillway blocks. Report matter to DRD Manager for engineering evaluation of the problem.

o Inspect the chute and flip bucket surfaces for evidence of cavitation or erosion. Make repairs immediately and report the matter to DRD Manager.

o Inspect chute for damage or displacement of chute blocks. Determine cause and repair or replace damaged blocks.

o Inspect the flip buckets and flip bucket apron. In case of any damage or deterioration, undertake and complete all repairs before the beginning of the rainy season. Deterioration of the flip bucket apron could progressively undermine the flip bucket and timely repair is essential.

o Inspect the elaborate chute damage system to determine if the drains are functioning properly. This system drains into galleries under the spillway chute. Clean the drains by rodding as necessary. Clean drains at least once a year just prior to the beginning of the rainy season. Correct deficiencies as necessary.

o Inspect the flip bucket apron drains and clean by rodding (or similar method) to prevent clogging. Minimum cleaning of once a year prior to the onset of the rainy season is highly recommended.

7.3.7 PLUNGE POOL AND OUTLET CHANNEL

The Plunge Pool and Outlet Channel are to be kept clear of obstructions to flow (such as gravel deposits and silt accumulations) so they will function properly.

The sides of the plunge pool are cut in rock, with rockbolts installed in the first thirty meters downstream from the flip bucket apron. There is a small possibility that successive spillway discharges will erode the side walls of the plunge pool back towards the flip bucket or cause slides which could retrogress in that direction. Thus the condition of the plunge pool slopes must be monitored very carefully and any necessary remedial action(s) must be taken immediately to ensure that the flip bucket is not undermined. Specific actions are:

o Inspect the side wall areas of the plunge pool as well as the base of the flip bucket apron for evidence of potential undercutting. There must be a yearly inspection by a diver on the concrete apron and the sidewall rock contact from the low plunge pool water level down to the foundations. Successive photographs should also be taken and reviewed.

o If undercutting is observed, report the matter to the DRD Manager for engineering evaluation.

o Inspect the plunge pool and outlet channel for development of obstructions.
o If it appears that obstructions are developing in the plunge pool and outlet channel due to sedimentary deposits or slides from adjacent slopes, report the matter to the DRD Manager for an evaluation to determine if removal of the material is necessary or whether action can be deferred and the problem monitored to see if the material is removed by spillway discharges.

7.3.8 POWER INTAKES

When the reservoir level is low enough, perform the following:

o Inspect concrete for evidence of deterioration. If there is significant deterioration or damage, analyze and determine the cause.

o In case of serious concrete deterioration, drawdown reservoir and undertake the needed repairs. The Central Office must be consulted on this matter.

o Inspect for evidence of differential settlements. Cross-check with foundation instrumentation data.

o If settlements are substantial (in excess of five millimeter) report the matter to the DRD Manager.

Note: Because the power intakes are submerged for long periods, the inspection should be done by a diver at a two-year interval. Procedures for inspection and maintenance of the trash racks, gate guides and sills, and other power intake equipment are discussed in Section 5.2 – POWER INTAKES

7.3.9 DIVERSION TUNNELS

When tailwater levels are low enough for tunnels to be accessible (on foot or by boat), perform the following:

o Inspect for increased seepage/leakage at the tunnel plugs and into tunnels through lining. Inspect for increased seepage/leakage around and/or outside of the tunnels.

o To the extent practicable, measure seepage/leakage from the tunnel roof and walls and record results. Check for flow pattern changes and change in color from clear to turbid. In case of changes, report it to the DRD Manager for evaluation.

o Impose restriction smoking or any other activity which could cause a gas explosion in the tunnels and observe strictly the personnel safety precautions listed in Section 7.3.1.

7.3.10 BALIGATAN OUTLET WORKS

o Inspect for seepage/leakage from the interior of the concrete outlet conduit. Specifically check the concrete plug located upstream of the spherical valve in the concrete conduit.

o Inspect for seepage/leakage around the outside of the outlet works.
Measure and record flows. Check for change in color from clear to turbid. Report increases in flows or color changes to the DRD Manager for further evaluation.

Check outlet works ventilation system for proper operation. Test for gas accumulations. Repair promptly as necessary so that gas concentrations do not develop.

7.3.11 FOUNDATIONS AND FOUNDATION DRAINAGE

Most of the actions pertaining to the foundations and foundation drainage are discussed in Section 6.4.3 – DATA COLLECTION AND REDUCTION. Following are notes on some particularly important other actions to be taken. (All personnel who routinely have to go into drainage galleries and adits to take readings and measurements shall perform the visual inspection listed. However, the Chief, Civil Works Section shall regularly perform the visual inspection at least once every six months).

- Inspect to see that the extensive system of drainage holes drilled from the foundation galleries are clean and draining the water from the foundation rock. If holes become clogged, flush or rod to clean, or if a drainage hole cannot be cleared, drill a replacement drainage hole nearby.
- Check for any changes in weathering of the rock in the galleries.
- Inspect for sloughs or slides from the gallery rock surfaces.
- In case of observed settlements or displacements of concrete structures or embankment, immediately inform the DRD Manager who shall order a special inspection of the foundation in the affected areas.
- Pay particular attention to the foundation in the vicinity of Station 0+231 in Drainage Gallery K and the exploratory adit excavated in a downstream direction from DGK. There is a series of upward and downward drainage holes in DGK (N) and DGK (S). In addition, movement indicating instrumentation devices are installed in the rock walls of the exploratory adit. In this area, monitor the flow from the drain holes for any unexplained changes in quantity or increase in sediment in the water. Take periodic measurements of the instrumentation for determination of any relative movements in any direction of the rock on the two side of the shear zone and with reference to the sides of the adit.
- IF ANY CHANGED CONDITIONS AS LISTED IMMEDIATELY ABOVE ARE DETECTED, REPORT THIS SITUATION AT ONCE TO THE DRD MANAGER FOR EVALUATION.

7.3.12 MARIS DIVERSION DAM

The MARIS Diversion Dam was modified at the time of construction of Magat High Dam to increase its capacity to regulate the daily discharges from the Magat Hydroelectric Plant. The dam is a low concrete gravity type structure with an overflow spillway along almost in its entire length. Because it is only a short distance
downstream from the Magat High Dam and Spillway and because the reservoir at MARIS is too small to provide for any flood storage, all large flood flows must be passed over the MARIS spillway. The design of the modifications provided for the very large spillway capacity within the limited length of the dam by keeping the ogee overflow crest lower than is needed for re-regulation storage and then provided for raising the reservoir level by use of stop logs on the spillway crest during normal operation. During large floods, depth of flood over the spillway crest will be quite deep. Therefore, the most critical aspect of the operation of the MARIS Diversion Dam is the of placing and removing of the stop logs to provide the necessary re-regulation storage and the necessary spillway capacity to prevent overtopping the stop logs or the dam crest.

The dam is a low concrete gravity structure and should be a relatively safe structure with minimum of problems. However, because of the very high flood flows that will occur from time to time, the spillway and the plunge impact area will be subjected to very strong and potentially damaging hydraulic forces. Because of the geologic conditions, the foundation of the impact area is particularly susceptible to erosion during high flows as has already been demonstrated on the right side near the abutment. Therefore, the following inspections and actions are to be undertaken:

- Inspect for evidence of erosion in the spillway impact area. Take photos, measurements, and soundings if necessary, to determine and monitor the extent of erosion. Report the matter to the DRD Manager. Remedial measures shall be taken immediately whenever any erosion threatens to undermine the impact apron.
- Inspect the approach to the spillway and keep it clean of obstructions. Remove accumulations of sediment, debris and driftwood on a regular basis in order to avoid interference with placing of the stop logs.
- Inspect the ogee, chute and flip bucket surfaces for evidence of cavitation, erosion or other damage. Make repairs at first opportunity and report to the DRD Manager. Repairs can be made when stop logs are in place during normal operation.
- Inspect for movement or displacement of each of the concrete gravity ogee blocks. Report any movement to the DRD Manager.
- Inspect concrete joints for evidence of leakage or damage. Report occurrences to the DRD Manager.

7.3.13 RESERVOIR AREA

a. GENERAL

Although it is unlikely that the reservoir area will affect the stability of the Magat Dam, it should be examined periodically for evidence of features that might compromise its safety. This examination should be done when the reservoir is close to its lowest level. The prime concern from the dam safety aspect is the possibility of reservoir slides which could generate waves capable of overtopping
the dam or of damaging its appurtenant structures. The following reservoir area features should be checked:

- Inspect the reservoir rim for potential landslides.
- Check (in the areas around the reservoir) for evidence of changes such as development of cracks, sinkholes, sloughs and settlement of roads or structures.
- Check for new operations around the reservoir area such as mining, timber cutting or groundwater extraction which might affect the stability of the slopes or cause sediment deposition in the reservoir.
- Inspect exposed reservoir bottom surface for depressions and sinkholes, or erosion of natural surfaces.
- Check reservoir rim for undercutting by wave action.
- Plot observations and unusual conditions on a reservoir record map. Record reservoir water levels at time of inspections.
- Notify the DRD Manager of any problem discovered during the reservoir inspection so that further evaluation and any necessary corrective action be taken.
- Regulate the operation of fish cages by setting guidelines. Monitor strictly adherence to these guidelines and imposed appropriate sanctions for offenders.

Note: 1. Reservoir area inspections should be made by means of boats with any suspect areas inspected on foot.

2. The National Irrigation Administration shall assemble a reservoir area mosaic from aerial photography taken in 1978 so that changes in the reservoir can be detected by comparing inspection results (including new photography in future years) with the “before reservoir” conditions.

b. RESERVOIR SEDIMENTATION

Sedimentation of the reservoir is a matter which needs to be measured and controlled to the extent possible and feasible.

The prime measure for controlling sedimentation is the maintenance of a high degree of forestation throughout the catchment basin. The rate of sedimentation has a direct effect on the economically viable life of the Magat Dam, and sedimentation in the upstream area of the reservoir has the potential for causing flooding in excess of that without the reservoir.

In order to monitor the depositions, a sediment range system for the reservoir and tributaries has been established. This system is shown on drawing 1187-F-H-2302 which is included in Volume 2. The system consists of 35 ranges located in these areas.
Main Reservoir - Dam to Alimit River - 16
Upper reaches of reservoir – Alimit River to Lamut River - 9
Bagabag Area, including Lamut River - 10

The coordinates and elevations of the range ends are marked with concrete monuments. A white concrete fencepost has been erected near each monument to assist in locating the range ends. Following are the actions to be taken on sedimentation monitoring:

- Resurvey the range at five year intervals during the life of the project. This will involve land surveys of the range line from the range ends to the water edge and hydrographic surveys of the part of the range that is submerged. For more efficient accomplishment, the surveys should be made during the dry season when the reservoir is low. Also, resurvey the ranges following a flood at the Magat Dam in excess of 8,000 cubic meters per second. The Survey should be done the following dry season.
- Once the range data are obtained, determine cross-sectional area of each range by planimetering or by calculating.
- Compute the volume of sediment in each reservoir segment by averaging the areas of two adjacent ranges and multiply by the distance between them. Sediment volumes in reservoir segment bounded by three ranges can be calculated using Eakins Range formula, which is included in Volume 2.
- Compare sediment range profiles with the original profiles which are included in Volume 2.

The original profiles surveyed by the National Irrigation Administration are the ones to be used.

- File all range survey data at the project office.
- Take samples of reservoir sediment deposits at five year intervals. Use core sampling to take samples from various areas of the reservoir. Perform graduation analysis on the sample, determine dry unit weights, make notes on material identification by visual inspection and record all the data from the sample by date and sample origin location.
- At the time of surveying the sediment ranges, survey also the Magat-Baligatan Connecting Channel and monitor the rate of sedimentation. Remove sediment as necessary so that the channel invert is not higher than Elevation 158.25 meters.

File all data for future reference. Label samples as to date taken and location and retain.
c. RESERVOIR WATER QUALITY

Reservoir water quality is discussed here primarily with respect to the potential for corrosion of dam structures and equipment (monitoring of the quality of the reservoir water also has implications on domestic and agricultural uses).

Corrosion of metal in contact with water, particularly rapidly flowing water, is a complex subject beyond the scope of this Manual. However, in general it can be assumed that acidity and high concentrations of dissolved oxygen are the prime factors which would produce high rates of corrosion on the exposed metal in the Magat Dam structures and facilities.

The following actions are to be taken relative to reservoir water quality and corrosion:

- Take water samples monthly from a location near the dam at three different depths (at reservoir water surface, at Elevation 155.00 and at mid-depth) and perform chemical analysis to determine:
  - pH
  - Dissolved oxygen, ppm
  - Total solids, ppm
  - Conductance, mhos
  - Magnesium, ppm
  - Chlorine, ppm
  - Sulfate, ppm
  - Carbonate, ppm
  - Bicarbonate, ppm
  
  File all records for future reference.

- Monitor analysis results, particularly for increases in acidity and dissolved oxygen.
- Observe for unusual odor coming from the water surface of the reservoir.
- Monitor corrosion of exposed metal. In the event of apparently excessive rates of corrosion, take water samples and analyze on a more frequent basis.
- In case of development of corrosion problems, consult an expert corrosion engineer to evaluate the situation and make recommendations for corrective action.

7.3.14 PROJECT ROADS AND SPILLWAY BRIDGE

For the proper operation and maintenance of the Magat Dam Complex, it is important that all features are easily accessible. Thus, all roads and the spillway bridge shall be inspected periodically and maintained in good condition. Of particular importance is the inspection and maintenance of the spillway bridge as this bridge provides the only assured quick access from one side of the dam to the other. This
bridge should be inspected thoroughly on a frequency of at least once per year to ensure that it is safe for carrying the design loads.

7.3.15 REPAIR CAPABILITIES

In order that repair of structures as mentioned in the previous sections of this Chapter can be performed expeditiously, the National Irrigation Administration shall, by prior general arrangement, either establish an onsite capability or ensure that the capability is readily available from local contractors, to perform the following general types of repairs:

- Maintenance and repair of all project service roads.
- Repairs to the embankments including embankment slope protection.
- General concrete repairs and/or replacements
- Rockbolting.

Following is a list of major items of construction materials which should be kept available for accomplishing these repairs:

- Road surfacing material - 10,000 cubic meters
- Large size quarry rock, suitable for Zones 9 and 10 - minimum of 20,000 cubic meters
- Filter material (Zone 2A) - 10,000 cubic meters
- Free draining rock (Zone 6) - 10,000 cubic meters
- Concrete aggregates, all sizes, and cement necessary for 1,000 cubic meters of concrete
- Rock dowels with anchor plates, 6 meter long, 25 mm diameter for use as rock bolts, 100 each.
- Appropriate quantities of timber, lumber, hardware, pipe and general supplies for accomplishing repairs.

Following is a listing of the minimum pieces of construction equipment that should be available at the site at all times:

- 1 – Mobil Crane, 35 ton capacity
- 1 – Road Grader
- 1 – Dozer, D6 or equivalent
- 1 – Front end Loader, 2 cu. yd. capacity
- 3 – Dump Trucks, 4 cu. m. capacity
- 1 – Concrete Mixer, ½ cu. yd. capacity
- 1 – Work Boat with barge
7.4 UNUSUAL OCCURRENCES OR EMERGENCIES

7.4.1 GENERAL

This Section provides instructions and information to aide the Manager, DRD and his staff during an emergency or unusual occurrence. Although some of the actions and procedures listed are contained in previous parts of this Manual, they are repeated here for convenience in reference.

As discussed later herein, THESE EVENTS ARE TO BE REPORTED IMMEDIATELY TO THE NATIONAL IRRIGATION ADMINISTRATION CENTRAL OFFICE IN QUEZON CITY. HOWEVER, AS COMMUNICATION MAY BE LOST AT THE TIME OF EMERGENCIES DUE TO TYPHOONS OR OTHER CAUSES, THE DRD MANAGER MUST TAKE ACTION ON HIS OWN IN THE ABSENCE OF INSTRUCTIONS FROM THE CENTRAL OFFICE. IT IS OF UTMOST IMPORTANCE TO MAINTAIN THE INTEGRITY OF THE DAM AND PREVENT A MAJOR DAM FAILURE. At the same time the DRD Manager is to take action to minimize the possibility of the loss of human lives and to minimize property damage in downstream areas.

The greatest threat to the Magat Dam is for the soil and rockfill embankments to be overtopped by flood flows. Therefore, the DRD Manager must assure that spillway gates are opened properly to pass flood flows. In order to accomplish this there must be assurance that the gates can be operated. After any unusual event or emergency, the actual capability to open the spillway gates must be demonstrated. If a gate cannot be operated, emergency actions must be taken by the DRD Manager and the Central Office to get the gate back into operation the shortest possible time.

A plan of action for warning people in the flood plain downstream of the dam regarding controlled or un-controlled water releases from the reservoir has to be prepared. The principles, procedures and implementing instructions for this action plan are contained in the Magat Dam Emergency Action Plan prepared by the National Irrigation Administration in conjunction with the civil and military authorities in the affected areas. The Magat Emergency Action Plan is included at the front of this Manual. In general this plan is based on the following elements:

a. Flood plain inundation maps have been prepared for five levels of flood releases.
b. Warnings will be issued commensurate with the area that is expected to be flooded by the releases and as required by the Emergency Action Plan.
c. The DRD Manager and the MARIIS OM are responsible in notifying all concerned Civil and Military authorities in the Region of expected discharge releases from the dam and the appropriate Zone Warning.
d. The Civil and Military authorities shall issue zone warnings by phones, radio, public radio broadcasts and by any other possible means.
e. The Civil and Military authorities will supervise and assist in the evacuation of people from the affected areas and in other measures to prevent or reduce flood damages.

f. Ten sirens have been installed in the inundation area to warn people within hearing distance of these sirens. These sirens are particularly applicable for warning people within the river reach between the MARIS Diversion Dam and its confluence with the Cagayan River at Gamu, Isabela.

7.4.2 REPORTING

An UNSUAL OCCURRENCE is an event that takes place or a condition that develops which is not normally encountered in the routine operation of the dam and reservoir. An EMERGENCY is an unusual occurrence of an extreme nature. An emergency situation exists if the unusual occurrence presents potential danger to the dam, appurtenant structure or persons within the area, particularly downstream of the dam.

The DRD Manager is to determine which of the above situations has occurred and take appropriate action, including reporting the event immediately to the National Irrigation Administration Central Office in Quezon City. The Central Office will proceed with appropriate actions, including advice as to frequency and type of additional reports required. All involved officials shall maintain a diary recording phone reports and discussions and keep a record of oral instructions given for the duration of the unusual occurrence or emergency.

The initial report should briefly cover the following:

- Subject: (what has happened and description/name of the incident)
- Time and date of start of incident:
- Location of incident:
- Summary of incident:
- Anticipated effects and decisions/instructions needed from Central Office with time limits for receipt of these decisions/instructions.

7.4.3 POSSIBLE DAM FAILURE

The DRD Manager must make a careful analysis of the situation and the structures to determine whether failure is a distinct possibility before taking the actions listed in this paragraph and issuing an emergency warning. As a major dam failure is a remote possibility, the DRD Manager is cautioned not to take premature action, to make all possible efforts to contact the NIA Central Office and to fully review the failure indicators before proceeding with the Emergency Action Plan and spillway release action hereto listed.
Signs of possible imminent dam failure would be:

- Water leaking from the downstream faces of the embankments or the abutments.
- Water leaking from the interfaces between the concrete headworks and the embankments.
- Greatly increased discharges from the drainage galleries or from the surface weirs.
- Water issuing from the downstream faces of joints in the concrete headworks.

If the dam is failing, or seems likely to fail, evacuation of the people from the flood plain must be completed as quickly as possible. The DRD Manager is to:

- Implement the Emergency Action Plan as quickly as possible
- Perform all emergency repairs possible to try to prevent the failure of the dam
- In the absence of instructions from the Central Office, open spillway gates to drawdown the reservoir limiting releases to a maximum of 8,000 cubic meters per second.

If a decision is made to draw down the reservoir because of the possibility of a dam failure, the spillway gates shall be opened to give a discharge of approximately 8,000 cubic meters per second with the seven ogee gates being raised to uniform openings. If the threat of failure of the dam increases such that in the judgment of the DRD Manager dam failure is very eminent, he shall open the gates further as necessary to save the dam.

Do not open the orifice spillway gates 8 and 9 until the reservoir falls to Elevation 185.00. The operating principle is to discharge 8,000 cubic meters per second for as long as the reservoir level will allow this or until the problem area is above reservoir water level.

7.4.4 EARTHQUAKE

Actions and procedures to be instituted are listed in ascending order of severity in the event of earthquake induced accelerations at the Magat Dam.

For Measured Site Earthquake Induced Accelerations of more than 0.05 gravity as measured by the strong Motion Accelerograph in Drainage Gallery K, a Modified Mercalli or Rossi Forrel Intensity VII earthquake measurement shall be used in lieu of the measured 0.05g if the strong Motion Accelerograph is not in operation.

Note: The listed order is the priority order, but the DRD Manager should be able to mobilize sufficient staff to accomplish several actions simultaneously.

(1) Read all of the acceleration measuring devices.
(2) Conduct a general overall visual inspection of the dam starting with the concrete headworks structures and the interfaces with the embankments.

(3) Visually inspect the low angle shear in Drainage Gallery K and take readings of the low angle shear instrumentation to determine whether there has been any movement in this shear zone.

(4) The outlet works conduit shall be inspected as soon as possible after the earthquake has occurred.

(5) Take readings of the instrumentation in the Right Interface (first) and the Left Interface. Reduce this data and plot promptly and compare with the established historical trends.

(6) Same as (4) above for the Inverted Plumblines and the TICs in the concrete headworks structures. Inverted Plumblines at the uppermost reading point are the first priority of this subparagraph.

(7) Same as (4) above for Drainage Gallery Weirs, DGE-1, DGI-1, DGL-1 and for surface measurement weirs WRA-1, WRA-2, W1A-L, WND-1.

(8) Notify the Central Office of any unusual circumstances or problems detected.

(9) Read, reduce, plot and make comparisons with historical trends for all remaining instrumentation devices.

(10) Proceed with further appropriate actions based on information obtained from preceding measures.

(11) If not already in place, mobilize spillway gate operating crews at the left interface spillway gatehouse. Check all communications.

(12) Check for availability of power to the spillway operating panels and to each of the spillway gates.

(13) Exercise and test the spillway gate emergency power system including a check for availability of an adequate fuel supply.

(14) Test and exercise all gates and hoists in the order of:

a. Ogee Spillway Gates
b. Orifice Gates
c. Power Intake Gates
d. Baligatan Dam and Outlet Works Gate (with spherical valve closed)
e. This should be permanently plugged now.

Note: These tests and gates exercises are to be performed only behind stop logs or bulkheads, if it has been determined that the reservoir will not be drawdown because of an emergency situation.

(15) Proceed with instrumentation readings, reducing and plotting as per “Special Events” column of Table 6.1, Chapter 6.

(16) If there is a possibility of dam failure, implement the Emergency Action Plan.
7.4.5 MAJOR FLOODS

Detailed instructions for passing floods through the dam are contained in Section 4.1.3 - Operations. In addition to actions covered by those instructions, the following are to be done:

a. FOR SPILLWAY DISCHARGE OF 4,500 CUBIC METERS PER SECOND OR MORE

(1) Take measures that can be accomplished to prevent worsening of any developing problems.
(2) Ensure that the stop logs at MARIS Diversion Dam are in the up position.
(3) Observe and record the performance of the entire spillway system, (approach channel, ogee crest, piers, power intake structures, spillway chute, flip bucket, plunge pool and spillway outlet channel) for the duration of the flood. Photographs and motion pictures should be used to record the hydraulic regiment.
(4) Take readings at six (6) hour intervals, of the standpipe piezometers located in the gallery at the lower end of the spillway chute.
(5) If there are indications of structures not performing as expected, after the flood, make a complete visual inspection of the dam project and institute “Special Events” frequency of instrumentation actions.
(6) Continuously report situation and actions taken to the Central Office.

b. FOR SPILLWAY DISCHARGES OF 20,000 CUBIC METERS PER SECOND, OR MORE

(1) Proceed as per (a) above.
(2) Monitor the condition of the MARIS Diversion Dam during the flood. Perform measures possible to preserve integrity of MARIS Dam.
(3) After the flood, institute “Special Events” frequency of instrumentation actions and perform complete visual inspection even though there are no apparent problems after the event.
(4) Perform complete inspection of MARIS Diversion Dam.
(5) Dam Safety Officer in the Central Office shall order a special dam safety evaluation and inspection immediately after the said Special Event.

7.4.6 OTHER SITUATIONS

There are other possible unusual occurrences or emergency situations; such as landslides, severe storms, sabotage, terrorism and rapid increases in flows from the foundations or through the concrete structures and embankments (more than 10% establish norms). For any or all of these, the principles discussed in the preceding parts of this Section are to be used as guidelines. The following summarizes the actions required.
(1) Keep all spillway gates in operational status at all times.
(2) Mobilize the full operations and maintenance staff on alert status.
(3) Try to eliminate or reduce the threat to the dam immediately.
(4) Ensure that all communications are working.
(5) Ensure that power is available to operate the spillway gates.
(6) Provide warning as appropriate to people downstream of the dam.
(7) Proceed with “Special Events” instrumentation readings and follow-up actions.
(8) In case of imminent dam failure, implement the Emergency Action Plan and make releases as necessary to try to save the dam or to delay the occurrence of failure. See Section 7.5.3.
Annexes
# FIRST DELIVERY OF SNAP CARS TO NIA-MARIIS

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<td>SATURNINO T. TENEDOR</td>
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Total: **P 87,823.44**
FLOOD OPERATION RULE FOR MAGAT DAM
Table 4.2 Gate Opening for Initial Operations

<table>
<thead>
<tr>
<th>Waterlevel Rise from DWL (m)</th>
<th>Spillway Discharge (m³/s)</th>
<th>No. 1</th>
<th>No. 2</th>
<th>No. 3</th>
<th>No. 4</th>
<th>No. 5</th>
<th>No. 6</th>
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Note: 190.00m AMSL is DWL for the non-flood season from October 1st to May 31st, unless otherwise specified by the FPWS Center.
<table>
<thead>
<tr>
<th>Waterlevel Rise from DWL (m)</th>
<th>Spillway Discharge (m³/s)</th>
<th>Gate Opening (m)</th>
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</thead>
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<tr>
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Note: 193.00m AMSL is DWL for the flood season from June 1st to September 30th, unless otherwise specified by the FFWS Center.
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<th>Instrument</th>
<th>Normal Condition Frequency</th>
<th>Special Events Frequency</th>
<th>Remarks</th>
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<tbody>
<tr>
<td>Piezometers</td>
<td>Twice Monthly first five years, then monthly</td>
<td>6 Hours</td>
<td>Until normalizing</td>
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<tr>
<td>Soil Pressure cells and Associated Piezometers</td>
<td>6 Hours</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TIC's</td>
<td>Quarterly first five years then each six months</td>
<td></td>
<td>Immediately after earthquake special event</td>
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<td>Extensometers</td>
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<td>DFSB Loops</td>
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<td>Inverted Plumbilines</td>
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<tr>
<td>Surface Settlement and Deflection Measurements</td>
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<td>Survey Elevations</td>
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<tr>
<td>Acceleration Measurements</td>
<td>Check daily and immediately after a tremor is felt at the site</td>
<td>12 Hours</td>
<td></td>
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<tr>
<td>Flow Measurement Weirs &amp; Pipes</td>
<td>Daily first five years, then daily during wet season and weekly during dry season with visual check daily</td>
<td></td>
<td>Four hour frequency if sudden increase in flow occur or change in color from clear to turbid. Continue checking until directed otherwise by the manager</td>
</tr>
<tr>
<td>Low Angle Shear Movement</td>
<td>Monthly</td>
<td></td>
<td>Immediately after earthquake special event. Continue checking daily until determination made that movement is not occurring.</td>
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</table>

* Five years to be measured from February 1, 1983
** Applies to crest points only. Measurements points or slope to be read only if nearby crest points indicate movements, vertically or horizontally of 2 centimeters or more between successive reading.
Figures
Figure 2.1
MAGAT RIVER INTEGRATED IRRIGATION SYSTEM
ORGANIZATIONAL CHART

 OPERATIONS MANAGER

OM's STAFF

ENGINEERING AND OPERATION

OPERATION SECTION

ENGINEERING SECTION

WATER CONTROL & MONITORING Section

EQUIPMENT MANAGEMENT

UTILIZATION & CONTROL

REPAIR & MAINTENANCE

INSTITUTIONAL DEVELOPMENT

FARMERS ORGANIZATION

FARMERS ASSISTANCE

ADMINISTRATIVE DIVISION

PERSONNEL & RECORDS

PROCUREMENT & PROPERTY

CASHIERING SECTION

GENERAL SERVICES

DISTRICT I

OPERATION & MAINTENANCE

EQUIPMENT

ADMINISTRATIVE

INSTITUTIONAL DEVELOPMENT

DISTRICT II

OPERATION & MAINTENANCE

EQUIPMENT

ADMINISTRATIVE

INSTITUTIONAL DEVELOPMENT

DISTRICT III

OPERATION & MAINTENANCE

EQUIPMENT

ADMINISTRATIVE

INSTITUTIONAL DEVELOPMENT

DISTRICT IV

OPERATION & MAINTENANCE

EQUIPMENT

ADMINISTRATIVE

INSTITUTIONAL DEVELOPMENT

DAM AND RESERVOIR DIVISION

CIVIL WORKS

ELECTRO-MECHANICAL

INSTRUMENTATION

ADMINISTRATIVE

WATERSHED MANAGEMENT
Figure 4.1

MAGAT RESERVOIR OPERATION RULE CURVE

<table>
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<th>Month</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
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<tbody>
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<td>End Elev, m</td>
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### Volume of Water, m³

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<th>Volume, m³</th>
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<tr>
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<td>345</td>
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### Water Surface Area, Ha.

- 2020: 12.3
- 2021: 23.4
- 2022: 34.5

### Storage Allocations

- Palm Beach Reservoir
- 1
- 2
- 3
- 4
- 5
- 6
- 7
BALIGATAN OUTLET WORKS
RATING CURVES

(ONE GATE IN OPERATION)

ELEVATION (M)

DISCHARGE (CU. FT/S)

FIGURE 49