"Hydrology for Small-Hydropower Generation"

October 28-November 10, 1984

Manila, Philippines

Course Description

and

Trip Report

Funded by the Office of Energy, U.S. Agency for International Development
Organized by the Small Decentralized Hydropower Program of the National Rural Electric Cooperative Association
Cosponsored by the National Electrification Administration of the Philippines

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Introduction

Thirty-one engineers participated in a small-hydropower training course, "Hydrology for Small-Hydropower Generation," held in Manila, Philippines, October 28-November 10, at the Hyatt Regency of Manila. The course was funded by the Office of Energy of the U.S. Agency for International Development through its Cooperative Agreement with NRECA in small hydropower under the Small Decentralized Hydropower Program, which organized the course.

NEA

The training course provided a good opportunity for NRECA to again work with the National Electrification Administration (NEA) of the Philippines, which served as the local cosponsor for the hydrology course. Working through the NEA in the late '60s and early '70s, NRECA helped the Philippines develop a management program for its rural electric cooperatives. The NEA's Mini-Hydro Development Office, headed by Zenaida Santos, provided crucial logistical and planning assistance prior to the course, particularly in the area of preliminary analysis of training needs in the ASEAN region, as well as providing much-needed logistical support during the course, including providing ground transportation, secretarial assistance, and A-V equipment.

Background

In June 1981, the SDH Program organized a regional workshop in Bangkok, Thailand, on small-hydropower development (the second in a series of four regional workshops). This week-long workshop looked at all aspects of the technology (technical, economic, management, and institutional) and attracted over 100 participants. Discussions were held at the workshop among participants from four of the Association of South East Asian Nations (ASEAN) led to the organization in 1982 of the Working Groups on Cooperation in Micro/Mini-Hydro Development under the aegis of the ASEAN network. The Working Groups were designed to share information among the participating countries on developments in the technology, including unique solutions to technical problems, cost-cutting designs and construction techniques, experience with equipment, etc. A major emphasis was placed on sharing information (course notes, etc.) on training programs, as well as in joint training efforts.

In 1982, the Working Group informally approached the SDH Program about developing a specialized training courses for the ASEAN countries. At about the same time, the SDH staff had concluded that, although the workshops were useful training mechanisms, a more thorough training course was needed that focused on a single topic in an expanded format with fewer participants from a smaller region.

The ASEAN countries provided an ideal audience. They had shown a willingness to cooperate--member countries were invited to send participants to training efforts organized by the individual countries; technical, sometimes embarassing, problems were discussed openly; and information developed locally or gathered from other groups involved in the technology were shared among the participating countries. In addition, the countries have similar hydrologic, climatic, geographic, and demographic characteristics.

In 1983, the Energy Office provided initial approval for the SDH Program to assess the primary training needs for two training courses for the ASEAN region during a visit to the region in June and July 1983. SDH staff members met with the country delegations headed by Hartoyo Notodipuro, PLN (Indonesia), who serves as Chairman of the Working

Groups; Zenaida Santos, NEA, Philippines; Rashidi Bin Tak, NEB, Malaysia; and Chartdanai Chartpolrak, NEA, Thailand.

In November 1983, the SDH Program provided two preliminary course outlines based on these meetings. In March 1984, the Working Group met in Chieng Mai, Thailand to discuss the training proposal. They approved the preliminary course outlines and requested that the first course, on hydrology, be held in Manila, Philippines. In April, the SDH Program's Training and Information Coordinator traveled to the region to make preliminary logistical arrangements for the course and to discuss in more depth the individual countries' training requirements in hydrology.

Each country supplied a preliminary course outline which the trainers subsequently synthesized into a general course outline (see Appendix A) which also highlighted specific problems each country noted. The primary focus of the course was on how to adequately assess hydrologic resources at sites where little or no data exist.

Trainers

Three hydrologists, Drs. Martin Johnson (The Johnson Co., Montpelier), Pedro Restrepo (Stone and Webster Engineering Corp., Boston), and Paul Kirshen (ERT Inc., Concord), and Allen Inversin (the SDH Program's Micro-Hydropower Engineer), developed and presented a series of interconnected lectures and class exercises. In selecting appropriate trainers, the SDH Program was most concerned with not only the trainer's grasp of the technical subject, but his experience with hydrology in developing countries. Both Drs. Johnson and Kirshen had assisted the SDH staff with previous training and technical efforts; Dr. Restrepo, a native of Colombia, had worked with the United Nations in evaluating several small-hydropower sites. Each trainer brought not only his unique capabilities in statistical, practical, or computer applications, but his own perspective as well.

Participant Selection

The participants (see Appendix B) representing both national utilities responsible for small-hydropower development and the private-sector engineering firms with which they work closely to design and build the small-hydropower plants, were selected with equal care--each had an engineering degree or equivalent work experience, currently worked in the area of hydrology or a related field, and had had coursework in statistics and computers. Since the course was presented in English, each participant had to have a good grasp of English.

Hydrologic Problems in Developing Countries

In considering just the hydrologic aspects of small-hydropower plant design, the basic needs are easily defined. At each site, there is a need for:

1. A **flow duration curve**--a graphical representation or record of the water typically available in the stream throughout the year. This is more critical for grid-connected plants where all the energy generated can find some use and there is, therefore, a need to maximize plant size subject only to economic constraints.

2. A knowledge of the **minimum flows** found in the stream. This is especially critical for isolated sites where minimum flows set the level of dependable power which will be available from the plant.

3. A knowledge of **floodflows** is critical for the sizing, layout, and design of the entire hydropower scheme, to protect each component from the ravages of flood waters. A knowledge of floodflows is necessary for both grid-connected and isolated schemes.

But whereas these three basic needs are easily defined and understood, meeting these needs is significantly more difficult. Records are often spotty, or interrupted, inaccurate, or are not available. Existing data-gathering networks should be reviewed in the light of the needs of a small-hydropower program and improved and expanded upon. Few have the luxury of waiting 5-10 years for the data to be gathered. One is therefore faced with the task of making the best use of whatever data are already available. One of the major objectivies of the course was to instill in the participants an understanding of the basic hydrologic, hydraulic, and statistical concepts and techniques so that they will be able to critically analyze all the available data, to know what is useful and what is not, to weed out erroneous data or to correct it, to process the data, and to cross-check all conclusions by using as many different approaches as possible to come up with the information required.

Computer Applications

The course also provided the participants with additional training in analyzing data using computers to process hydrologic data. This included an initial refresher session in BASIC, the standard language of micro- and mini-computers used by most engineers, as well as how to use and program a plotter. The sessions focused on statistical techniques in hydrologic analysis (i.e., flow simulation from rainfall when flow data are not available) with an introduction to stochastic hydrology (the statistical properties of hydrologic processes) illustrating these techniques with simple exercises (i.e., streamflow series generation, statistical analysis of mean/standard deviation, correlation coefficient, double mass curves, etc.). A major focus of these sessions was to illustrate that, whereas the computer is a valuable tool in the search for a solution, a thorough understanding of hydrology is still required to ensure that this tool is effectively used, that without this understanding of hydrologic phenomena, the computer printout alone, although impressive, may well be incorrect and misleading.

Training Methodology and Course Exercises

Recognizing that effective learning is significantly enhanced if the learner is personally involved in the learning process, problem-solving was a major component of the training effort. Most of the problems (see Appendix C) were based on hydrologic data (rainfall and streamflow) obtained from the National Energy Administration of Thailand for the northern-most region of Thailand. An initial series of classroom exercises was designed as an introduction to, or as a review of, basic approaches to processing hydrologic data. This was followed by a series of exercises in applying these approaches to predicting the hydrologic parameters--the flow duration curve and miniumum and maximum flows—at a specific site in Thailand for which no hydrologic data were initially provided to the participants. After predicting these parameters, the participants had a chance to compare their findings with the "answer" which was actual streamgaging data from that site.

These exercises enabled the participants to begin to understand more fully the specific issues facing those attempting to determine the flow regime in a stream, to more critically analyze various approaches and understand the limitations of each and to realize, although it my not be fully satisfying, that there is frequently no final answer as there may seem to be on a unversity exam paper. Getting as close to predicting real world phenomena as possible is the real challenge which faces these participants when they return to their respective countries.

On the last day of the training course, the trainers tested the participants' knowledge of the topic with a brief comprehension evaluation (see Appendix D). Unfortunately, no test was administered on the participants' arrival (before the course began). A summary of the test scores is provided in Appendix E. The private-sector engineers generally did much better than their government counterparts. In analyzing this, the trainers concluded that this was probably due to better technical training (most of the private-sector engineers were trained in the U.S. or U.K.) as well as more experience (they tended to be older and more specialized in their work). Comprehension of English did not seem to be a major factor (the Thai delegation did quite well on the test, in spite of some problems with the language, whereas, several of the Filipino participants, for whom English is essentially their mother tongue, did not do as well). In addition, it was clear that two or three of the participants had difficulty with engineering basics (in spite of the fact that they had degrees in engineering). The organizers and trainers concluded that it would be advisable, in spite of the logistical problems that it might pose, to test the prospective participants' knowledge of engineering basics in addition to the topic in which training will be provided.

Field Exercise

Although there were no small-hydropower sites near Manila which could be incorporated as an integral component of the training course, participants visited a small stream about one hour south of Manila. Personnel from the First Cavite Electric Cooperative, Inc. at Dasmarinas, which serves the area, assisted the trainers in locating the field trip site. With basic tools and materials provided by both the trainers and the NEA, four groups of participants were each assigned to make the necessary measurements to determine the flow in the stream. Additional measurements were taken to determine the roughness coefficient of the stream so that a rating curve could be prepared. From measurements of the riverbed, it was illustrated how these physical characteristics could be used to determine bankfull flow, which in turn could be used to estimate mean annual flow in the stream. Trainers found that some of the participants needed assistance with using the measuring devices and concluded that skills in and knowledge of such equipment should be incorporated in the selection criteria for subsequent courses.

Manufacturers' Display

As with previous training programs, the SDH staff invited U.S. equipment manufacturers to provide displays/brochures/etc. to be displayed during the course. Eleven U.S. equipment manufacturers (see Appendix F) displayed information about their product lines. In addition, other publications which the SDH Program has found useful in its previous training efforts were made available. These included SDH Program publications, as well as other publications developed by Tudor Engineering Company, the World Bank, etc.

Evaluations

Appendix G provides a sample of the evaluation form the participants were asked to complete regarding the course content, structure, exercises, trainers, logistical arrangements, etc. Participants' responses were generally quite enthusiastic about the course, although most felt that more time was needed to cover the material adequately. Appendix H summarizes the participants' responses.

Costs

Appendix I lists the costs for the training course. The initial budget submitted for the training course included a budget of approximately $135,000. The actual costs for the course totaled approximately $125,000 (this is probably somewhat high because it includes estimates of the costs for travel and per diem for the participants which the Missions have not yet provided).

Recommendations

Appendix J summarizes the recommendations provided by the participants, trainers, cosponsor, and organizers.

Follow-Up Evaluation

During the discussion evaluating the course on the last day of the training course, participants felt that a follow-up evaluation would be useful in gauging how useful the training course had been. The course organizers agreed to send such a follow-up evaluation to each participant and his/her supervisor after 5-6 months had elapsed. Appendix K lists tentative questions to be included in the follow-up evaluation form which will be sent out in March.

Additional Training Needs and Possible Sources of Funding

In meetings with the participating national utilities, USAID Missions, and international financial institutions following the training course, the SDH Program's Training and Information Coordinator noted that the Energy Office was reassessing its small-hydropower strategy and that there may not be a second course funded through the SDH Program as earlier cable traffic and correspondence had indicated. It was made clear, however, that AID was interested in seeking out additional sources of funding and therefore, had approved additional travel and per diem funds for the SDH Training Coordinator to try to locate additional funding.

The ASEAN Working Group representatives were grateful for the time, money, and effort expended in the first course, which they felt had been highly successful. They reiterated their interest in a second course. They indicated that, as noted previously, the next course should be in site layout and design and that, furthermore, it should be held in Kuala Lumpur, Malaysia, in November 1985. Primary needs in this topic area included soil mechanics (with particular emphasis on erosion and sedimentation), cost-cutting techniques, the appropriate use of computers in designing civil works, and standardized designs where appropriate, with an emphasis on field work during the course.

Several possible sources of funding were located. These include:

1. UNDP/Bangkok--either on a subregional (ASEAN) basis or through the UNDP's small-hydropower training center in Hangzhou (organized by UNIDO); both UNDP and UNIDO were especially impressed with the training methodology used in the hydrology course--that of a practical course with class and field exercises, with careful attention given to selecting trainers and participants;

2. individual Mission training funds (USAID/Jakarta's General Participant Training Program, which could fund travel and per diem for government participants from Indonesia; USAID/Bangkok's Problems of Emerging Development, which could fund travel and per diem for participants from Thailand; and

3. Asian Development Bank—was interested in a longer-term training course, in the area of economic analysis for small rural energy systems; although the Bank is interested primarily in training bank personnel, other participants would be welcome.

Both the UNDP and ADB indicated that they would look more favorably on a request for funding for training in small hydropower if another international development organization (such as USAID) would fund some portion of the costs.

Appendix A. Course Outline

Sunday, October 28

3:00	p.m.	WELCOMING REMARKS, Elizabeth Graham, Training and Information Coordinator, Small Decentralized Hydropower Program, NRECA
3:20	p.m.	HISTORY AND ACTIVITIES OF THE ASEAN MINI-HYDRO WORKING GROUP, Zenaida Santos, Executive Director, Mini-Hydro Development Office, NEA
3:40	p.m.	USAID-FUNDED ACTIVITIES IN THE ASEAN REGION, Bruce Blackman, ASEAN Regional Liaison Officer, USAID/Manila
4:00	p.m.	A NATIONAL RURAL ELECTRIFICATION PROGRAM - THE PHILIPPINES EXPERIENCE, Keynote address, General Pedro Dumol, Administrator, NEA
5:00	p.m.	COURSE OVERVIEW, Allen Inversin, Micro-Hydropower Engineer, Small Decentralized Hydropower Program, NRECA
5:30	p.m.	RECEPTION

Monday, October 29

8:30 a.m. COURSE INTRODUCTION - Martin Johnson

9:00 a.m. BASIC HYDROLOGY (to understand the basic concepts of hydrology that relate to small-hydropower design and operation, with particular emphasis on the physical features causing different hydrologic characteristics or regimes) - Paul Kirshen

Hydrology and hydropower
- o Energy amount and timing
- o Low flow
- o Floods
- o Sediment
- o Tailwater
- o Evapo-transpiration losses from ponds
- o Water quality
- o Competition with other uses
- o Uncertainty

Hydrologic cycle
- o Unifying concept of hydrology
- o Components--precipitation, evapo-transpiration, runoff, groundwater storage, consumption
- o Spatial and temporal variation of components

Climatology and weather
- o Definitions
- o Global circulation
  - Heat
  - Earth's rotation/spinning
  - Land/water masses
- o Anti-cyclones/cyclones
- o Fronts
- o Temperature
- o Humidity/Evaporation
- o Wind
- o Examples and explanations of regional precipitation patterns

Precipitation
- o Formation steps
- o Types and causes--convective, orographic, cyclonic, boundary layer
- o Temporal and spatial variation
- o Examples and explanations of regional precipitation patterns

9:45 a.m. BREAK

10:15 a.m. Precipitation/runoff processes
- o Precipitation
- o Interception
- o Surface storage
- o Infiltration
- o Surface and subsurface flow
- o Variable source concept

Groundwater hydrology
- o Types of groundwater formations
- o Impacts on streamflow

Mass balances for river basins

Hydrographs and flow duration curves
- o Definitions
- o Components and why
- o Separation of components
- o Shapes and causes

Geomorphology (to introduce the concepts of geomorphology as they relate to hydrology, to define terms that will be used later in the course, and to explain some useful field applications of geomorphology to hydrologic predictions) - Martin Johnson
- o Descriptions of fluvial processes in geomorphology
- o Terms and definitions
- o Some (apparently) worldwide correlations
- o Suggested applications

12:45 p.m. LUNCH

2:00 p.m. Stochastic nature (to introduce the concepts of randomness, stochasticity, probability, and probability distributions and to illustrate with examples the stochastic nature of the hydrologic processes) - Pedro Restrepo

- o Random events
- o Random variables (definitons and examples)
  - Discrete
  - Continuous
- o Stochastic processes (definitions and examples)
- o Probability and probability distributions

Working group session - Using the appropriate data for two different areas within the ASEAN region, derive qualitative relationships between precipitation, streamflow, and elevation; review streamflow and precipitation patterns; predict expected flow variations and discuss implications for small-hydropower generation

3:30 p.m. BREAK

4:00 p.m. Working group session (cont.)

Tuesday, October 30

8:30 a.m. COUNTRY PAPER

9:15 a.m. HYDRAULICS FOR HYDROLOGISTS (to become familiar with Manning's equation and its applications to free-surface steady uniform turbulent flow) - Martin Johnson

Open channel flow and its classifications
- o Types
- o States
- o Regimes

Open channels and their properties
- o Kinds
- o Channel geometry
- o Velocity distribution
- o Measurement

Energy and momentum principles
- o Energy
- o Critical state
- o Momentum

Critical flow
- o Section factor
- o Computations
- o Control
- o Flow measurement

Uniform flow and its formulas
- o Chezy formula and Chezy resistance
- o Manning's formula and roughness coefficient (including tables and illustrations of latter)

11:00 a.m. BREAK

11:30 a.m. Working group session
- o Continuity problem
- o Critical depth problem
- o Log-log regression of flow vs. stage (rating curve)

12:45 p.m. LUNCH

2:00 p.m. Working group session
- o Computation of uniform flow using Manning's formula and design of channels

3:30 p.m. BREAK

4:00 p.m. Working group session
- o Headwater curve using weir flow (critical depth) formulas
- o Tailwater curve using Manning's equation
- o Net head duration curve
- o Canal design (earth, non-erodable)

Wednesday, October 31

8:30 a.m. STATISTICS FOR HYDROLOGISTS (to introduce basic statistical concepts and techniques used for hydrologic analysis) - Pedro Restrepo

Basic concepts (definitions and examples)
- o Expected value
- o Sample
- o Variance and covariance
- o Standard deviation
- o Correlation coefficient
- o Skewness
- o Histograms

Probabilistic models (univariate)
- o Normal distribution
- o Log-normal distribution
- o Extreme-value distributions
  - Gumbel
  - Pearson's
- o Other distributions commonly used in hydrology and examples of applications
  - Exponential
  - Gamma
  - Poisson

Use of probability distributions
- o Plotting positions
- o Model fitting

10:15 a.m. BREAK

10:45 a.m. Working group session
- o Computation of mean, variance, correlation coefficient, skewness
- o Preparation of histograms
- o Fitting of data to different distributions

12:30 p.m. LUNCH

2:00 p.m. Probabilistic models (multivariate)
- o Jointly distributed variables
- o Joint normal distribution
- o Conditional distributions

Error estimation and consideration
- o Number of observations
- o Independence of observations

Regression analysis
- o Bivariate and multivariate
- o Parameter estimation by least squares
- o Data transformation
  - Power transformations
  - Logarithmic transformations
- o Error analysis
  - Estimation error
  - Error in the parameters

3:30 p.m. BREAK

4:00 p.m. Working group session - regression analysis problems covering each of the areas covered in the lecture

Thursday, November 1

HOLIDAY (for interested participants, computers and instruction in computer operation, programming, and problem solving will be available)

Friday, November 2

8:30 a.m. COUNTRY PAPER

9:15 a.m. **DATA ACQUISITION** (to understand design and evaluation of precipitation and streamflow measurement networks) - Paul Kirshen

Introduction
- o Summary of use of hydromet data in design of small-hydropower stations
- o Primary emphasis upon precipitation and streamflow data
- o Special studies and long-term networks
- o Measurement frequency

Measurement
- o Precipitation
  - Non-recording
  - Recording
  - Costs
  - Accuracy
  - Station selection, design, and maintenance

10:45 a.m. BREAK

11:15 a.m.
- o Streamflow
  - Rating curves, weirs, direct discharge measurement
  - Non-recording
  - Recording
  - Costs
  - Accuracy
  - Station selection, design, and maintenance

Network design and operation
- o General guidelines for different types of basins
- o Evaluation of existing networks
- o Review of techniques for estimating errors and impact on network design - Pedro Restrepo

12:45 p.m. LUNCH

2:00 p.m. Recording and telemetry systems (descriptions, including relative costs, sophistication, etc.)
- o Observers
- o Data-loggers
- o Cable
- o Telephone
- o Radio
- o Satellite
- o Other

Working group session - design short- and long-term gaging strategies for small-hydropower development in an ungaged section of a country

3:30 p.m. BREAK

4:00 p.m. INTRODUCTION TO FIELD TRIP EXERCISE (to review specific tasks to be accomplished during the Saturday field trip) - Martin Johnson

Saturday, November 3

8:00 a.m. FIELD TRIP (to collect the field data necessary to derive Manning's roughness coefficient for a streambed and its bankfull flow and to estimate the mean annual flow from these parameters)

Sunday, November 4

FREE

Monday, November 5

8:30 a.m. DATA TREATMENT (to illustrate data problems and to introduce methods of data manipulation, data extension, and bad data identification) - Pedro Restrepo

Data analysis
- o Varying quality of data
    - Occasional errors (cause, identificaton, and correction)
    - Systematic errors
    - Causes:
        - Relocation of stations
        - Upstream uses of water--regulation, flood protection, irrigation, water supply, water imports and exports
    - Techniques for identification and correction of errors (use of double-mass curves)
- o Varying frequency of observation
    - Frequency of sampling
        - Precipitation
            - For mean areal precipitation estimates
            - For flood forecasting
        - Streamflow
            - Dependency of frequency of sampling on the catchment's size
- o Varying periods of record

10:15 a.m. BREAK

10:45 a.m. Data correction
- o Extending records and filling gaps
    - Correlation techniques
    - Mention of Kalman filter
- o Treatment of bad records

- o Computation of basin averages
  - Thiessen's polygons
  - Isohyetal
  - Arithmetic average
  - Kriging

12:15 p.m. LUNCH

2:00 p.m. Working group session
- o Problems dealing with occasional errors using regression

3:30 p.m. BREAK

4:00 p.m. Working group session
- o Problems dealing with systematic errors using double-mass curve techniques
- o Computation of basin averages (using all methods noted above except Kriging)

Tuesday, November 6

8:30 a.m. DATA APPLICATION TO GAGED BASINS (to develop a feeling for hydrologic concepts and techniques by applying these to basins with available data)

Construction of frequency curves - Pedro Restrepo
- o Annual duration series
- o Partial duration series

Design floods
- o Use of probability paper for computation of design floods

Minimum flows
- o Frequency of droughts for firm energy estimation

10:15 a.m. BREAK

10:45 a.m. Working group session
- o Construction of frequency curves using annual and partial duration
- o Computation of design floods using both Gumbel and Pearson techniques

12:30 p.m. LUNCH

2:00 p.m. Power estimates - Paul Kirshen

Competing uses
- o General discussion
- o Complementary and competing aspects
- o Incorporation of effects into design and operation
  - Flow duration curve adjustment

3:30 p.m. BREAK

4:00 p.m. Working group session
- o Given detailed data for a specific area, derive annual energy expected at site using mean annual flow, monthly mean flow, daily flow duration curve, and weekly average flow for typical year and discuss applicability to various levels of study
- o Given irrigation demands at same area, reflect this in energy estimates for the above area

Wednesday, November 7

8:30 a.m. COUNTRY PAPER

9:15 a.m. DATA APPLICATION TO UNGAGED BASINS (to apply the concepts and techniques learned to cases where little data are available) - **Martin** Johnson

Collecting and sorting of data
- o Length, period, consistency
- o Accuracy, poor data, missing data, extension of data
- o Poor and spurious correlations
- o Rules of thumb

10:00 a.m. BREAK

10:30 a.m. Field observations
- o Topography, relief, land forms
- o Land wasting processes
- o Land use, conservation practices, vegetation
- o Soils, impedence, mottling
- o Geology--rock, strike, dip, fracture, incision
- o Groundwater well logs, yields, aquifers
- o Extractions
- o Channels--size, roughness, condition, debris

12:00 noon LUNCH

1:30 p.m. Consistency and extension of records
- o Double-mass curve
- o Five-year moving average
- o Flow duration curves

3:00 p.m. BREAK

3:30 p.m. Channel geometry
- o At-a-station geometry
- o Use of bankfull flow
- o Applications and limitations
- o Meander length

Thursday, November 8

8:30 a.m. APPLICATIONS TO UNGAGED BASINS (cont.)

Predicting floods
- o Dimensionless frequency curves
- o Worldwide data
- o Channel geometry

10:00 a.m. BREAK

10:30 a.m. Predicting mean annual flow
- o Interbasin correlations
- o Meander length
- o Channel geometry
- o Precipitation-streamflow model

12:00 p.m. LUNCH

1:30 p.m. Predicting flow duration curves
- o Dimensionless flow duration curves
- o Interbasin correlations
- o Short-term records

3:00 p.m. BREAK

3:30 p.m. Predicting low flow
- o Short-term base flow
- o Groundwater-streamflow relations
- o Basin examination
- o Extreme-value frequency curves

7:00 p.m. BANQUET

Friday, November 9

8:30 a.m. COUNTRY PAPER

9:15 a.m. EROSION AND SEDIMENTATION - Martin Johnson

Sedimentation

Definitions of types of sediment

Theory of transport

Transport equations and results

10:15 a.m. BREAK

10:45 a.m. Trap efficiency

Sources of sediment

The universal soil-loss equation

12:00 p.m. LUNCH

2:00 p.m. WATERSHED MANAGEMENT - Severo Saplaco

3:00 p.m. BREAK

3:30 p.m. BASIS OF DESIGN FOR SITE "X"

Data to be derived:
- o Drainage area
- o Flood flows
- o Mean annual flow
- o Flow duration curve
- o Low flow
- o Head
- o Installed capacity
- o Power canal
- o Sediment

Saturday, November 10

8:30 a.m. COMPUTER APPLICATIONS (to provide the opportunity for participants to familiarize themselves with the application of computers for solving hydrologic problems and to discuss in further detail specific problems facing them in their work) - Pedro Restrepo

10:00 a.m. BREAK

10:30 a.m. COMPUTER APPLICATIONS (cont.)

12:00 noon LUNCH

2:00 p.m. COMPUTER APPLICATIONS (cont.)

2:30 p.m. BREAK

4:00 p.m. CLOSING COMMENTS

Appendix B. List of Participants

Indonesia

Yandi Hermawan*
Civil Design Engineer
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Concord, Massachusetts 01742

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Appendix C. List of Course Exercises

1. Basic hydrology--review the basic geographical, topographical, and climatalogical factors which influence weather and, therefore, streamflow

   - o explain how the geography and topography of the region affect the climate and hydrology of various portions of Southeast Asia
   - o prepare a flow-duration curve from stream-gaging data

2. Hydraulics--review the basic hydraulic concepts which are relevant to understanding of hydrology

   - o apply the continuity equation
   - o review critical depth through application to overflow problem
   - o apply Manning's equation to a mountain stream
   - o develop a headwater rating curve over a broad-crested weir and a tailwater-rating curve through a gorge
   - o prepare a head-duration curve
   - o derive design parameters for a power canal

3. Statistics--review the basic statistical concepts which are necessary to analyze and synthesize hydrologic parameters

   - o derive mean annual flow, standard deviation, coefficient of skew, lag-1 serial correlation coefficient from field data and then fit normal and log-normal distributions to flows
   - o fit a linear regression model to flow data, computing the r^2 value, the correlation coefficient, the error in the parameters, and the standard error in the estimation
   - o fit a linear regression model to the log of the flow data and discuss validity of each model for reconstructing flows
   - o determine the correlation between the flow and elevation for sites in northern Thailand, group points by region, discuss trends in the data, and recompute yield vs. elevation models for each region

4. Data acquisition--description of the instrumentation and techniques involved in the acquisition of data

   - o design augmentation of existing precipitation and streamgaging network using WMO criteria

5. Data treatment--review of techniques for analyzing, questioning, and treating data

   - o review spurious correlations (focusing on the need to visually analyze data before applying any mathematical techniques)
   - o discover systematic errors in data through the use of double-mass curves
   - o prepare mean areal precipation estimates by Thiessen and isohyetal methods

6. Data application to gaged basins—these exercises permit the application of the ideas covered to date to geographical regions where data is available in order to derive the basic hydrologic parameters required for the planning of hydropower projects; application to gaged basins permits a review of the basic concepts without getting bogged down in the fact that the data is not available

- o prepare flood frequency curves by both the Gumbal and Pearson's methods after analyzing data and discarding spurious data
- o analyze energy production using both the mean monthly flows and the flow-duration curve

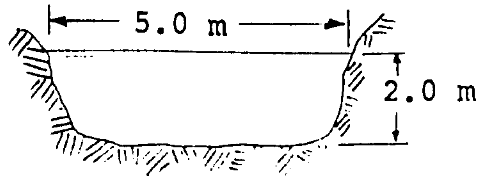
7. Data application to ungaged basins--deriving the basic hydrologic parameters as in the previous section but this time for basins with little or no data

- o use five-year moving average to analyze trends in data
- o apply a series of approaches to estimating the mean annual flow at an "ungaged" basin in northern Thailand
- o derive the flow-duration curve for the "ungaged" basin using a number of different approaches
- o estimate minimum streamflow
- o develop a rainfall-runoff model (optional)

8. Erosion and sedimentation--review the causes of erosion, quantify this phenomenon, and predict its impact on reservoir life

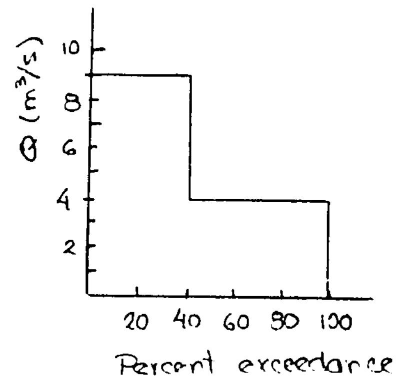
- o determine reservoir life using the concept of trap efficiency

A. What is the roughness coefficient of a channel with a slope of 0.005 which conveys a flow of 5.0 m^3/s? The Channel cross-section is shown at the right.



____

B. The flow duration curve for the flow at a 5.2 m drop along an irrigation canal is shown at the right. If a turbo-generating unit with an efficiency of 85% is placed at the drop, what is the maximum power available from that unit if all the flow is used?



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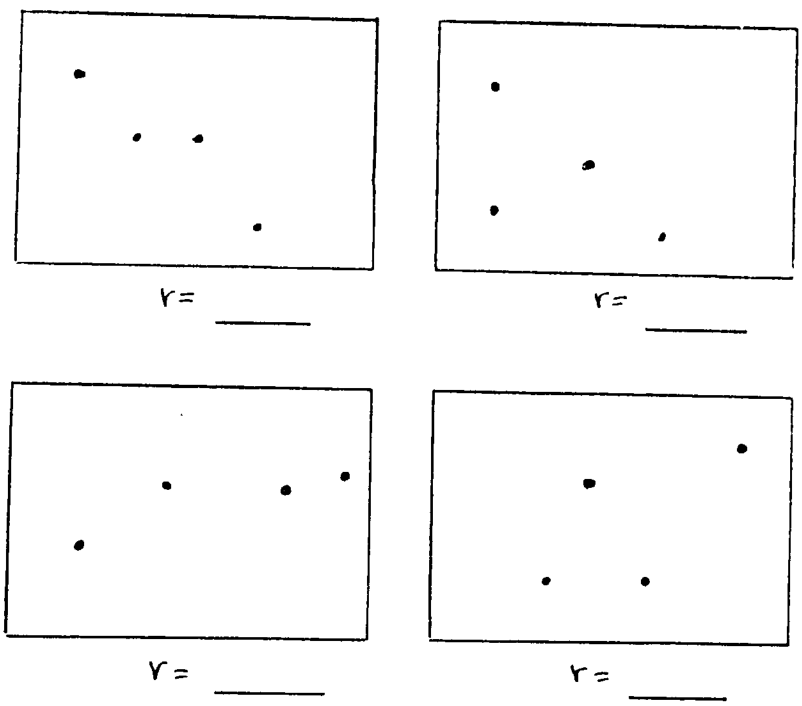
What is the total energy which is potentially available during one year?

____

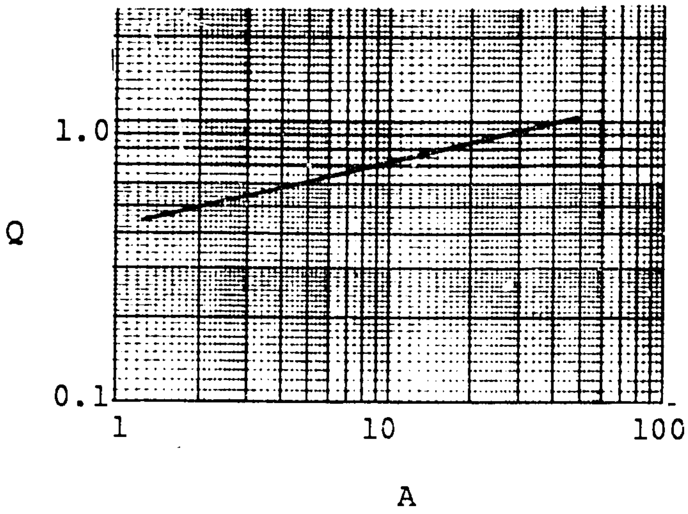
C. At the right are shown four sets of data. For each set, draw the regression line by eye.

The four correlation coefficients associated with these four sets of data are 0.60, -0.94, 0.85, and -0.57. Match each coefficient with the appropriate set of data.



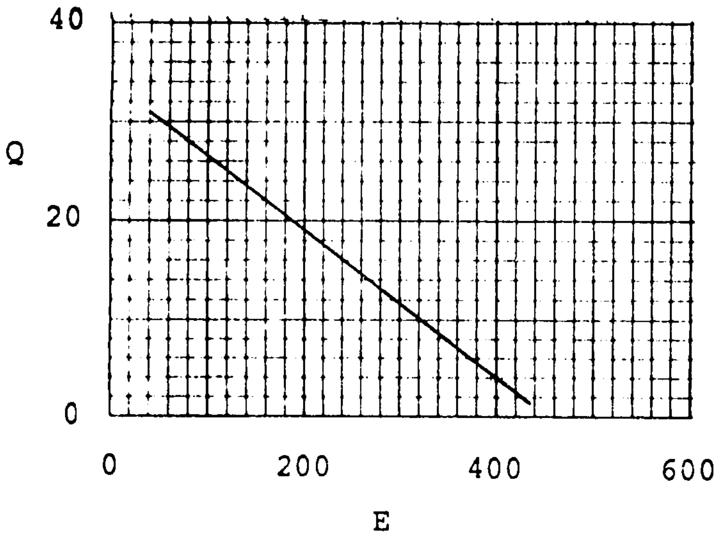
D. Write the equation of the line shown in each of the following graphs:

1.



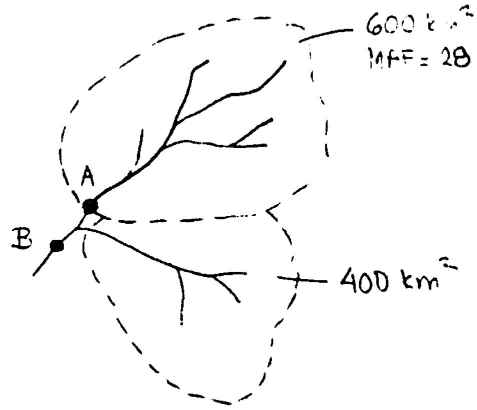
Q =

2.



Q =

E. Data from a gaging station at A is shown at the right. A hydro site is planned for site B. It will operate under a head of 10 m. Estimate the power which will be available at the site.



____

F. During 1982, streamflow measurements made every 18 days are shown below. Prepare a flow duration curve for 1982.

0.58	0.55	0.55	0.64	6.0	2.5	1.3	1.7	1.0
0.90	0.82	0.85	0.80	0.76	0.72	0.68	0.60	0.56

Appendix E. Summary of Scores from Comprehension Evaluation

Participants	Thailand	Philippines	Indonesia	Malaysia
1.	35	11	25	40
2.	34*	29*	7	40*
3.	38	29	22	40
4.	31	23	28	40
5.	31	28	31*	
6.		20	26	
7.		39	35*	
		40*		
Average score	34	27	25	40

Maximum possible score = 40
Mean score = 32
Mean score for private-sector engineers = 35
Mean score for government engineers = 29

*Denotes private-sector participant.

Appendix F. List of Equipment Manufacturers Displaying Materials

Axel Johnson Engineering
Mini Hydro Division
1514 N.W. 46th Street
Seattle, Washington 98107

Byron Jackson Pump Division
Borg Warner Industrial Products, Inc.
200 Oceangate Boulevard, Suite 800
Long Beach, California 90802

Essex Turbine Company, Inc.
Kettle Cove Industrial Park
Magnolia, Massachusetts 01930

Hayward Tyler
80 Industrial Parkway
P.O. Box 492
Burlington, Vermont 05402

Layne and Bowler, Inc.
1993 Chelsea Avenue
P.O. Box 8097
Memphis, Tennessee 38108

Hydro-Technology Systems
(formerly Little Spokane Hydroelectric)
P.O. Box 82
Chattaroy, Washington 99003

McKay Water Power, Inc.
P.O. Box 221
West Lebanon, New Hampshire 03784

Phoenix Power Systems, Inc.
1515 N.W. Ballard Way
Seattle, Washington 98107

Sverdrup
801 North 11th Street
St. Louis, Missouri 63101

Westinghouse Electric Corporation
Hydro Projects and Services Group
875 Greentree Road, Building 8
Pittsburgh, Pennsylvania 15220

Worthington Division
McGraw-Edison
5310 Taneytown Pike
P.O. Box 91
Taneytown, Maryland 21787

Appendix G. Training Course Evaluation Form

Your evaluation of this course is essential if future courses are to be even more effective. While we are interested in learning about what aspects of the course you found were well done, we are even more interested in useful criticisms you may have. The following evaluation is only useful to us if you give some thought to the responses you make and are open in your responses. Engineers from your country attending the next course will benefit from the improvements we make based on your evaluation.

1. Before arriving in Manila, what did you expect to learn in the course?

____

____

____

____

2. For your purposes, what was the most important topic covered? Why?

____

____

____

____

3. What seemed unnecessary or too elementary? Why?

____

____

____

____

4. Was the level of technical difficulty appropriate? _____ If not, explain.

____

____

____

____

5. Did you feel prepared for this course? ______ Is there some way that we could better prepare participants for future course (i.e., perhaps by sending participants a text-

book/other materials in advance of the course)? _______
What other way would you suggest (be specific)? ________

6. Have you found the computers in this course useful? ___
Would you have preferred to have spent more time using them? _____
What specific techniques were you hoping to cover and were they covered sufficiently? ____________________

7. What have you learned that you feel can actually be applied to your current position immediately? For instance, based on what you learned in the course, what will you do differently or what procedures will you implement on your return?

8. Listed below are a number of factors that we believe are significant in evaluating the trainers and their presentations. Please evaluate each trainer in each of the 9 categories below (excellent, good, fair, poor) and explain why. (please use the back of the page if necessary)

	MARTIN J.	PAUL K.	PEDRO R.
A. Organization and clarity of presentation			
B, Were enough examples cited during the lectures			
C. Clarity of blackboard work			
D. Usefulness and appropriateness of problems			
E. Voice (clarity, strength, speed)			
F. Speed of presentation			
G. Clarity of response to participants' questions			
H. Trainers' command of material (based on presentation, handouts, and exercises			
I. Did trainers have adequate understanding of the conditions and problems in the ASEAN region			

9. Was the field trip to gage a small stream a useful part of the course? ____ Why? ______________________________

____

____

____

How would you change the field trip to make it more useful (i.e., spend half a day on how to take accurate field measurements, use instruments, etc.)?

____

____

____

____

10. Would you find it useful to have some kind of follow up? _____ What form would it take? (i.e., should we poll your reactions to the course 6 months from now to see how it has affected your work)?

____

____

____

____

11. Was it useful to do the working group exercises as a group with the resource people circulating among participants or would you rather have broken into smaller groups with one resource person per group? ________________________

Why? ____

____

____

____

____

12. Was the course format of lectures and working group excercises effective in itself and was the distribution of time given to each appropriate? ____ Explain _______

____

____

____

Should time have been set aside for discussion following each lecture? exercise? _____ Explain ________________

____

____

____

____

____

Was the overall time allotted for the course (2 weeks) too long? ______ too short? ______ just right? ______

Why? ____

____

____

____

____

13. Was the course notework useful? ______ Appropriate? ____ Well organized? ______ Complete? ______

How would you have changed it?

____

____

____

____

____

____

14. Were the conference room facilities satisfactory (i.e., could you see and hear everything from where you were sitting)? _____ If not, what suggestions do you have?

____

____

____

____

Appendix H. Summary of Responses from Course Evaluation Form

Content

Participants found the material challenging and relevant. Statistics and Data Application to Ungaged Basins were thought to be especially important within the ASEAN context where data are extremely scarce.

Technical Difficulty

Participants found the level of technical difficulty appropriate. Most felt prepared for the course but felt it would be beneficial if materials could be sent ahead of the course so that they could be better prepared.

Working Group Exercises

Working group exercises were deemed very useful. It was suggested that in the future, instead of working on the class exercises as a group with resource people circulating among the participants, it would be more useful to break up into smaller groups with one resource person per group.

Course Format

The course format of lectures and working group exercises was generally felt to be effective. However, it was felt that more discussion time was needed. One suggestion was to allocate 30 minutes every morning to discussing the previous day's exercises.

Field Trip

Participants considered the field trip to gage a small stream very useful. A second one-day field trip to an actual site was also suggested. Another suggestion was to conduct the field trip exercises near a streamgaging station so that data acquired could be counterchecked with data on record.

Country Papers

It was generally felt that a country case study would be more beneficial than country papers.

Training Facilities

Training facilities, while adequate, could have been better. There was general agreement that an actual classroom would have been more conducive to learning.

Course Organization

The course was too short for the amount of material covered. In addition to more lecture and discussion time, an extra day for a second field trip was also strongly recommended.

Trainers

Overall, the participants rated the trainers good to excellent. Presentations were clear and well organized and relevant examples were cited. Problems provided were thought to be useful and appropriate. Participants comments on the problems included "very relevant for the ASEAN region" and "very forward looking." Trainers were thought to be responsive to questions and gave clear and direct answers. Several participants mentioned that trainers were available for questions outside of class time as well as during class, which was quite useful. Participants generally felt that the trainers had a good understanding of the conditions and problems unique to the ASEAN region and that their presentations reflected this. Participants also commented on the fact that examples cited were good, not only because they were relevant to the region, but also because they were based on actual experience that the trainers had had in the field.

Appendix L. Summary of Course Costs

Consulting Fees	
Johnson	$27,898.41
Restrepo	16,093.52
Kirshen	20,150.89
Total Consulting Fees	$64,142.82
Travel	
Participants	$10,902.00*
SDH Staff	7,690.62
Trainers	8,565.63
Total Travel	$27,158.25
Per Diem	
Participants	$10,035.00*
SDH Staff	7,374.93
Trainers	4,023.00
Total Per Diem	$21,432.93
Other expenses (printing, bus and equipment rental, banquet/reception, local assistant, etc.)	12,829.50
Total Training Course Costs	$125,563.50**

*Estimated; Missions had not sent final costs for travel and per diem for participants.

**In addition, there were many "in-kind" contributions of staff time (NEA, participating Missions which handled travel and per diem arrangements for participants, ADB and other observers) as well as equipment (NEA provided a-v equipment, photocopier, etc.). In addition, private-sector engineering firms paid travel and per diem expenses of 10 participants in the course; the USAID/Jakarta Mission paid travel and per diem expenses of one local staff engineer.

Appendix J. Summary of Recommendations

Course Content

1. Instead of having each country present a "country paper" giving status of small-hydropower development, have each country present a case study outlining a specific problem at an existing site and providing sufficient data/backup materials for participants to analyze the problem and make recommendations

Course Structure

1. Send course materials in advance of training course

2. Allot more time for discussion

3. Allot more time for computers

4. Include at least one trip to a field site (even if it is not germane to, or an integral part of, the course)

5. Test participants knowledge at beginning and at end of course

6. Increase number of days for course and have shorter hours each day

7. Make homework assignments and collect them each morning

Logistical Arrangements

1. Hold the course in an actual classroom

2. Do not have group (set) lunches; instead allow participants to go out for lunch and encourage group dinners to help break up the long day

Trainers

1. Have trainers speak very slowly

2. Allot specific time for them to meet with participants following class

Participants

1. Test for basic engineering skills and knowledge of training topic prior to selection

2. Test for English skills so that trainers know in advance who may have difficulty

Cost-Cutting Suggestions

1. Write to U.S.-based computer companies in the earliest stages of course planning outlinging computer needs and requesting free computers

2. Locate local engineering firm during trip to make preliminary logistical arrangements that might be interested in funding reception/banquet for course participants

3. Get firm commitment in advance of course from local cosponsor indicating what assistance they will provide

4. Increase number of private-sector engineers (who pay own travel and per diem costs)