COMPARISON AND USE OF HYDROLOGICAL NETWORK DESIGN AIDS NARI AND NAUGLS

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ABSTRACT

The World Meteorological Organisation project HYNET uses a technique, based on random subsampling of real data, to compare network designs with common objectives. Two network design aids, Network Analysis for Regional Information (NARI) and Network Analysis Using Generalised Least Squares (NAUGLS), were applied to data from a network of 76 water-level recording stations in North Island, New Zealand. NAUGLS conveys more information than NARI for maximizing regional information about mean flows given a limited budget. NAUGLS is applied to low flows, mean flows and flood peaks for the Nelson region, South Island, to illustrate its use.

INTRODUCTION

In 1984, at the Seventh Session of its Commission for Hydrology, the World Meteorological Organization (WMO) set up a project to compare technologies used by hydrological and meteorological services of its member countries to design networks. This project is known as Intercomparison of Operational Hydrological Network Design Techniques (HYNET).

WMO member countries, including New Zealand, have participated in comparing two network design aids developed and used in the United States of America (Moss and Tasker, 1991). The methods are Network Analysis for Regional Information (NARI) and Network Analysis Using Generalised Least Squares (NAUGLS). Both are in a HYNET computer program (Moss and Tasker, 1990).

These aids aim to define networks that efficiently provide information for estimating statistical variables of streamflow at ungauged sites in a homogeneous region. Estimation is based on a multiplicative regression model of a streamflow variable against physiographic and climatic characteristics.

NARI uses ordinary least squares to calibrate the regression relation and is based on simulations using stochastic hydrology. NAUGLS uses generalised least squares (Stedinger and Tasker, 1985) in which values of computed streamflow characteristics at each gauged site are weighted in inverse relation to the estimate of their precision. NAUGLS does not rely on simulation and is more mathematically elegant than is NARI. However, NAUGLS entails some simplifying assumptions in developing its weighting scheme. HYNET enables us to test whether the added elegance is a practical improvement over the more simplistic NARI.

HYNET uses randomly selected subsets from existing hydrologic data to simulate the design and evaluation of a network. Repeated sampling provides statistics describing the effectiveness of the network design in addressing a specified common objective. These statistics form a basis for comparison.

Both NARI and NAUGLS can design networks to estimate any one of several streamflow characteristics (e.g., see Tasker and Moss, 1979; Tasker, 1986). For the HYNET project, the objective was to minimise the mean square error of estimation of mean annual discharge at ungauged sites in a homogeneous region. Homogeneity is desirable since NARI and NAUGLS find optimum networks by using random errors; heterogeneity jeopardises this by introducing systematic errors. Homogeneity should also lead to reliable discharge estimators for ungauged drainage basins.

This paper reports the results of the HYNET comparison for mean annual discharge data from North Island, New Zealand. NAUGLS is then applied to the Water Resources Survey water-level recording network in the Nelson region of South Island, for annual low, mean and peak flows.

NEW ZEALAND HYNET RESULTS

Study Region

The HYNET study was limited to North Island, New Zealand (Fig. 1) because its climate and topography are less variable than those of South Island. North Island is hilly, with only small proportions of mountains and plains. Average annual precipitation is about 1800 mm for the northern two-thirds of the island, and about 1400 mm for the southern third. Topography largely dictates rainfall. Centrally located volcanoes (up to 2800 m) and barrier ranges (up to 1600 m) have average annual precipitations exceeding 2400 mm, with extremes exceeding 6000 mm. Precipitation is relatively evenly distributed throughout the year, with a slight winter maximum.

Hydrology of the Region

Annual runoff increases from about 200 mm for lower-lying land, rain-shadow areas and absorbent volcanic regions to about 5000 mm for drainage basins in higher rainfall zones. Average monthly discharge generally is highest in the winter months (June to September). Spring snowmelt does not contribute significant runoff to most North Island rivers.

Data Selection

Streamflow data for the North Island were screened to select the largest number of stations with complete records for the longest consecutive period. Seventy-six stations had complete records for 1971–1990. Drainage areas range between 0.3 and 6600 km^2 and mean annual precipitations range between 900 and 4200 mm (Appendix 1).

Tests for Homogeneity

It is not clear whether North Island is a homogeneous hydrological region. In flood hydrology studies, Beable and McKerchar (1982) split North Island into several geographical regions, whereas Mosley (1981) found no statistically significant clustering. McKerchar and Pearson (1990) established contour patterns for specific mean annual flood, indicating some heterogeneity. Hutchinson (1990) defined seven subgroups in a low flow study.

The regional homogeneity of the data was examined using the multiplicative regression model used by NARI, NAUGLS and HYNET. Logarithms of mean annual discharge (Q) for each of 76 gauging stations were regressed against

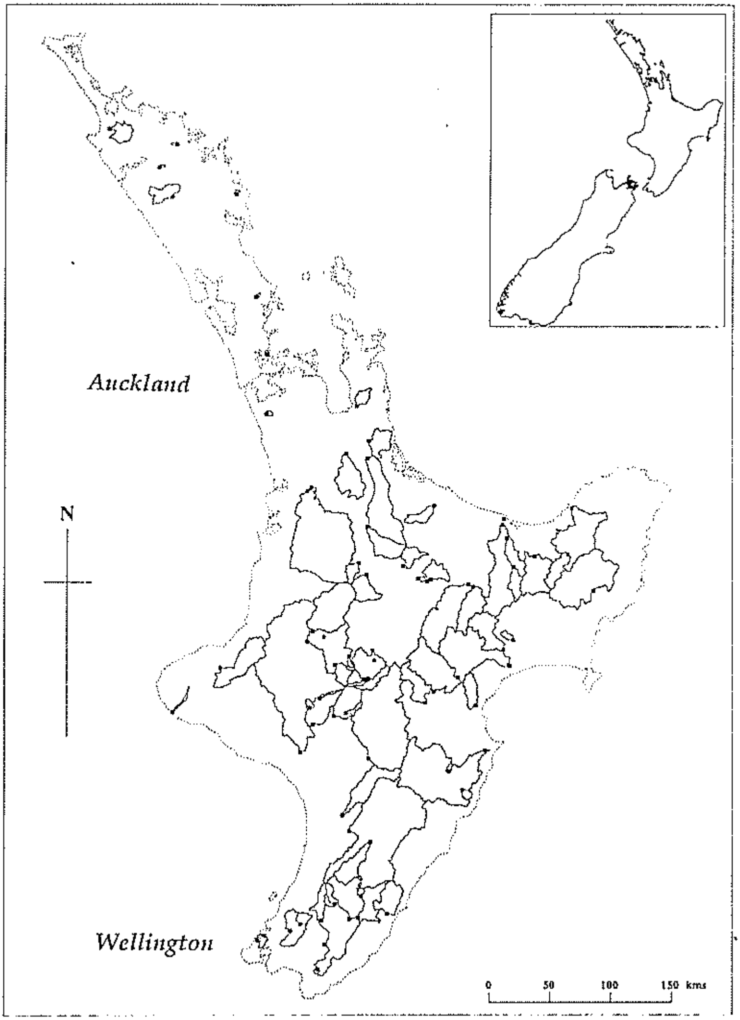

FIG. 1—Location of 76 North Island (New Zealand) gauging stations (squares, with upstream catchment boundaries) used for the HYNET study.

logarithms of two independent variables, drainage area (A) and mean annual precipitation (P). The resulting regression is:

$$Q = [2.10 \times 10^{-7}]\, A^{1.04}\, P^{1.56}$$

where Q is in m^3/s, A in km^2 and P in mm. The coefficient of determination of the logarithmic regression is 99%. The factorial standard error is 1.29, implying a standard error of estimation of approximately +29% or –23%. A plot of mean

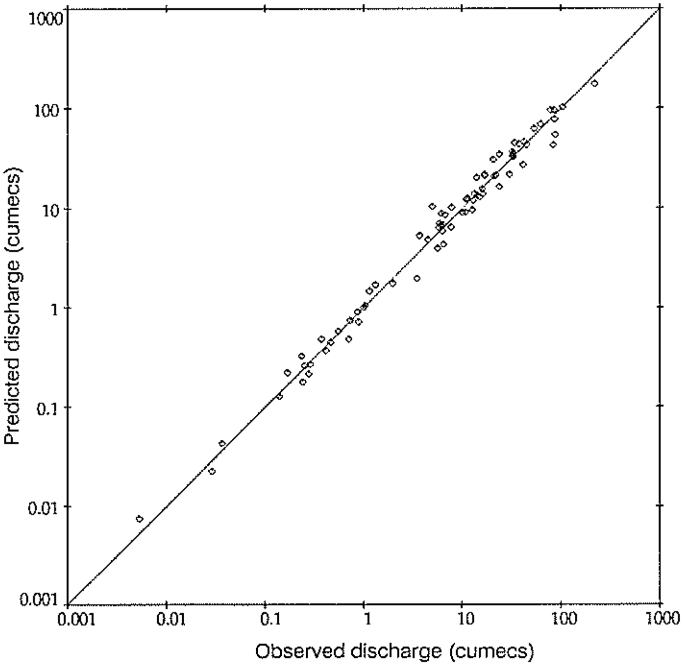

FIG. 2—Predicted versus observed mean annual discharge from logarithmic regression on drainage area and mean annual precipitation for the 76 North Island stations used for the HYNET study.

annual discharge estimates against those derived from the regression (Fig. 2) shows no unusual outliers. A map of residuals (Fig. 3) shows regression overestimates for locations where runoff is low due to absorbent volcanic soils (central North Island) and around central North Island volcanoes where rainfall may have been overestimated, and regression underestimates for southern-most catchments. A south-west to north-east trend from underestimation to overestimation is suggested (Fig. 3). However, because of the overall goodness of fit of the regression, and the need for a substantial HYNET data-base, for the purposes of this study it was assumed that the North Island is a homogeneous hydrological region.

Discharge data for each station are from the New Zealand Water Resources Archive, and drainage areas for each catchment are from Hutchinson (1990) and Walter (1990). Mean annual precipitation for each catchment was obtained directly from New Zealand Meteorological Service isohyetal maps (New Zealand Meteorological Service, 1985). Information on New Zealand hydrometric data quality is given in Mosley and McKerchar (1989).

HYNET Experiments

HYNET allows comparison of network design for a range of data availability and budgetary conditions. Thus we can compare NARI and NAUGLS used

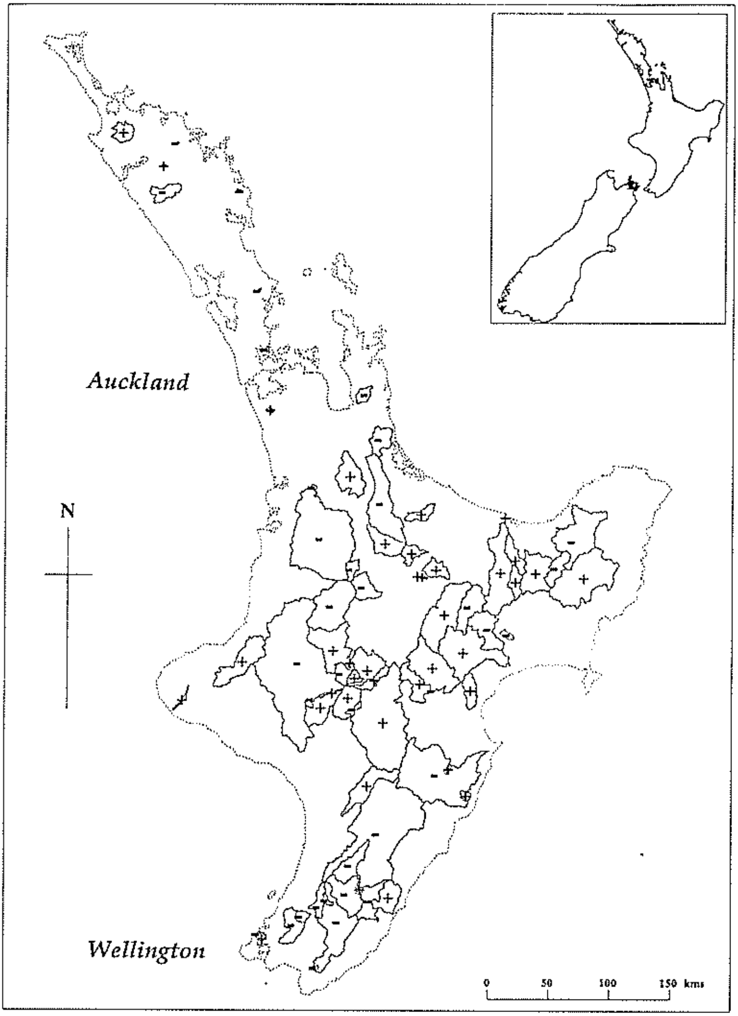

FIG. 3—Positive residuals (+) representing overestimation and negative residuals (–) representing underestimation computed from logarithmic regression of mean annual discharge on drainage area and mean annual precipitation.

with either sparse or more comprehensive data, and with an austere or more generous budget. For convenience, the initial experimental design consisted of two facets:

(1) Parameters to describe data availability
NB Number of gauges that provide data for the initial regressions. For sparse data we use 10 individual gauge records; for more comprehensive data, 30 records.

L3 Lengths of available records. L3 is the longest record length for each data availability condition. Three record lengths and the percentage of records of each length are selected for each condition. For sparse data we use records of 5, 8 and 10 years, with 30, 40 and 30% respectively of the records being of each length. For comprehensive data we use record lengths of 8, 12 and 15 years with 30, 40 and 30% of each length.

(2) Parameters describing constraints to the design

NP Number of gauges that can be operated in the future — a budgetary constraint. Under an austere budget, we use 10 gauges; under the generous budget, 40 gauges.

PH Length of the planning horizon — a time constraint. Two planning timespans are considered: 5 years (short) and 10 years (modest). The limitation of 20 years (1971–90) for the New Zealand data necessitated adjustment of parameter values for the combination of comprehensive-data and modest planning horizon; L3 drops from 15 to 13 years, and planning horizon from 10 to 7 years.

Each facet contains four pairs of conditions. Combining the two facets results in 16 scenarios, each of which defines an experiment suitable for HYNET. Moss and Tasker (1991) recommend additional experiments using alternative values within the range already defined. Therefore a further two experiments were conducted, where 20 records are available, with longest records of 10 or 15 years, a planning horizon of 10 and 5 years respectively, and funds for 25 gauges during the planning horizon.

Table 1 summarises the conditions assumed in all 18 experiments.

Computer program HYNET runs the NARI and NAUGLS techniques. For each loop of HYNET, a network is simulated by randomly sampling NB gauges with prescribed "present" record lengths. Both NARI and NAUGLS optimally select NP gauges from the pool of 76 gauges to operate for PH "future" years. The selection aims to minimise mean square error of prediction for mean annual discharge. "Projected" estimates of the mean square error of each regional logarithmic regression equation at the end of the planning horizon are made using the NB gauges by both NARI and NAUGLS before the planning horizon begins. "Realisation" of the next PH years facilitates new NARI and NAUGLS logarithmic regressions for Q. These regression equations are applied to all 76 sites to obtain post-planning horizon mean square error estimates from NARI and NAUGLS. The differences between the projected mean square errors and the achieved mean square errors are recorded. This is repeated 100 times.

The mean square error differences are summarised by bias and root-mean-square error performance statistics. Bias is the average tendency for the projected mean square error to either over-or underestimate the achieved mean square error of the regional mean discharge equation. Positive bias implies that the network design chosen for the planning horizon was better than required, i.e. over-design. Negative bias implies under-design. Root-mean-square error reflects the closeness of the projected and achieved mean square error of the regional equation: smaller root-mean-square errors correspond to greater precision. The results are given in Table 2.

HYNET Conclusions

For the eighteen New Zealand HYNET experiments in Table 2, NARI and

TABLE 1—Eighteen HYNET experiments for North Island mean annual discharge data.

Date Availability	Design Constraints		Design Parameters			
Number of gauges (NB) Length of available records (L3)	Budget (NP)	Planning Horizon (PH)	NB	L3 (yr)	PH (yr)	NP
Few, short records	Austere	short	10	10	5	10
	Austere	modest	10	10	10	10
	Adequate	short	10	10	5	40
	Adequate	modest	10	10	10	40
Few, long records	Austere	short	10	15	5	10
	Austere	modest	10	13	7	10
	Adequate	short	10	15	5	40
	Adequate	modest	10	13	7	40
Many, short records	Austere	short	30	10	5	10
	Austere	modest	30	10	10	10
	Adequate	short	30	10	5	40
	Adequate	modest	30	10	10	40
Many, long records	Austere	short	30	15	5	10
	Austere	modest	30	13	7	10
	Adequate	short	30	15	5	40
	Adequate	modest	30	13	7	40
Some, short records	Medium	modest	20	10	10	25
Some, long records	Medium	short	20	15	5	25

NAUGLS bias statistics were all positive. Hence both over-designed the precision of North Island regional mean flows equation. For each experiment, NAUGLS was less biased and so more accurate in projecting the equation's mean square error. More importantly, the root-mean-square error statistics (Table 2) show that NAUGLS outperformed NARI in every experiment. Hence, besides greater accuracy, NAUGLS also was more precise in projecting the regional equation's mean square error. The NAUGLS technique conveys more accurate and precise information than the NARI technique in analysing hydrological networks of mean annual flows for North Island, New Zealand. This conclusion is valid for reliably estimating mean square errors of regression models which is important for network managers. However, the underlying regression model may be wrong, and unreliable for estimating discharge at ungauged drainage basins.

NAUGLS APPLICATION TO NELSON

Water Resources Survey Water-level Recording Network

The Water Resources Survey's water-level recording network in the Nelson region, northern South Island is used to illustrate the use of NAUGLS. This network

TABLE 2—Summary of results for HYNET comparison of NARI and NAUGLS using North Island annual mean discharge data.

Exp. No.	NB	L3 (yr)	PH (yr)	NP	Bias (%) NARI	Bias (%) NAUGLS	Root mean square error (%) NARI	Root mean square error (%) NAUGLS
1	10	10	5	10	2.68	0.87	10.24	5.10
2	10	10	10	10	2.78	0.85	10.93	4.88
3	10	10	5	40	2.56	1.02	10.09	4.65
4	10	10	10	40	2.63	1.05	10.78	4.63
5	10	15	5	10	3.10	0.76	6.97	4.86
6	10	13	7	10	3.42	0.90	6.90	4.91
7	10	15	5	40	2.75	0.74	6.53	4.45
8	10	13	7	40	3.17	0.84	6.55	4.49
9	30	10	5	10	1.24	1.15	3.20	2.69
10	30	10	10	10	1.38	1.18	3.18	2.72
11	30	10	5	40	1.18	1.16	3.12	2.71
12	30	10	10	40	1.30	1.15	3.08	2.65
13	30	15	5	10	1.13	0.86	2.57	2.31
14	30	13	7	10	1.32	0.94	2.74	2.44
15	30	15	5	40	1.01	0.80	2.51	2.25
16	30	13	7	40	1.22	0.91	2.66	2.39
17	20	10	10	25	2.09	1.14	3.95	3.18
18	20	15	5	25	1.52	0.84	3.42	2.78

faced a reduced budget in 1991 and required technical input to help rationalise its future operation (M.P. Mosley, pers. comm., 1991). Using existing stations in the network, regional multiplicative regression equations for low flows, means, and flood peaks are determined based on basin area and mean rainfall. Given the number of sites to be operated over a planning horizon, NAUGLS selects the network most likely to improve the precision of each regional equation. Table 3 and Figure 4 show the water-level recording network.

Of the 23 sites (Table 3), six are eligible for closure (58301, 58902, 93209, 93211, 93213, 93214), and one was closed in 1990 (93212). One of the 23 sites (58904) was opened in 1989. For the purposes of this analysis, it was considered to be a new site for operation in the planning horizon.

Flow statistics used were annual minimum 7-day mean flow, annual mean flow and annual maximum flood peak (provided by A. Robinson, pers. comm., 1991). The longest record was for site 93213, which opened in 1934. Data up to and including 1990 were used for most sites. Mean annual values (Q_{LOW}, Q_{MEAN}, Q_{PEAK}) for each flow statistic are shown in Table 3.

TABLE 3—Nelson Water Resources Survey water-level recording network.

Site Number	River	Area (km²)	Annual Rain (mm)	Start Year	Discharge Q_{LOW} (m³/s)	Q_{MEAN} (m³/s)	Q_{PEAK} (m³/s)
52003	Aorere at Devils Boots	573	5190	1976	13.0	71.2	2270
52902	Takaka at Harwoods	260	2520	1975	2.30	15.1	456
52916	Cobb at Trilobite	46.8	3710	1969	0.395	3.77	95.1
57009	Motueka at Woodstock	1750	1950	1969	9.47	59.9	1130
57014	Stanley Brook at Barkers	81.6	1270	1969	0.0199	1.32	63.2
57022	Hunters at Weir	5.02	2150	1977	0.00277	0.0792	2.33
57502	Wairoa at Gorge	464	1970	1957	2.35	16.8	750.
58301	Collins at Drop Structure	17.6	1550	1960	0.0676	0.570	30.1
58902	Pelorus at Bryants	375	2300	1977	2.19	20.9	937
58903	Rai at Rai Falls	211	1770	1979	1.99	12.5	348
58904	Pelorus at Wakamarina	852	2170	1989	—	—	—
59201	Kenepuru at Kenepuru Hd	29.9	1800	1980	0.0621	6.45	180
60108	Wairau at Tuamarina	3430	1610	1960	15.0	128	2070
60110	Waihopai at Craiglochart	764	1570	1960	3.01	29.7	444
60114	Wairau at Dip Flat	505	1710	1951	9.03	26.8	368
60120	Branch at Weir Intake	550	1930	1983	4.93	22.5	571
93202	Buller at Longford	1410	2050	1963	23.5	74.4	699
93209	Maruia at Falls	980	2370	1963	17.6	58.0	817
93211	Matakitaki at Mud Lake	857	2340	1963	21.1	55.4	713
93212	Mangles at Gorge	284	2380	1958	2.15	9.81	170
93213	Gowan at L Rotorua	368	2380	1934	10.1	26.6	85.7
93214	Matiri at Lake Outlet	136	3960	1979	2.62	13.5	185
93216	Buller at L Rotoiti	195	1880	1951	4.25	12.9	74.1

Prior to the NAUGLS analysis, the regional homogeneity of the Nelson Water Resource Survey network was analysed using multiplicative regression models used by NAUGLS for each flow variable. Ordinary least squares fits to Nelson data are:

$$
\begin{aligned}
Q_{\mathrm{LOW}} &= [7.08 \times 10^{-10}]\, A^{1.39}\, P^{1.83} \\
Q_{\mathrm{MEAN}} &= [2.57 \times 10^{-5}]\, A^{1.03}\, P^{0.96} \\
Q_{\mathrm{PEAK}} &= [5.38 \times 10^{-3}]\, A^{0.87}\, P^{0.78}
\end{aligned}
$$

where the units are the same as those in Table 3. The mean annual low-flow logarithmic regression had a coefficient of determination of 88% and factorial standard error of 2.39; for mean flows, coefficient of determination was 92% and factorial standard error was 1.69; and for mean annual flood peaks, logarithmic regression coefficient of determination was 79% and factorial standard error was 2.12.

Plots of regression predictions against observed values show larger scatter

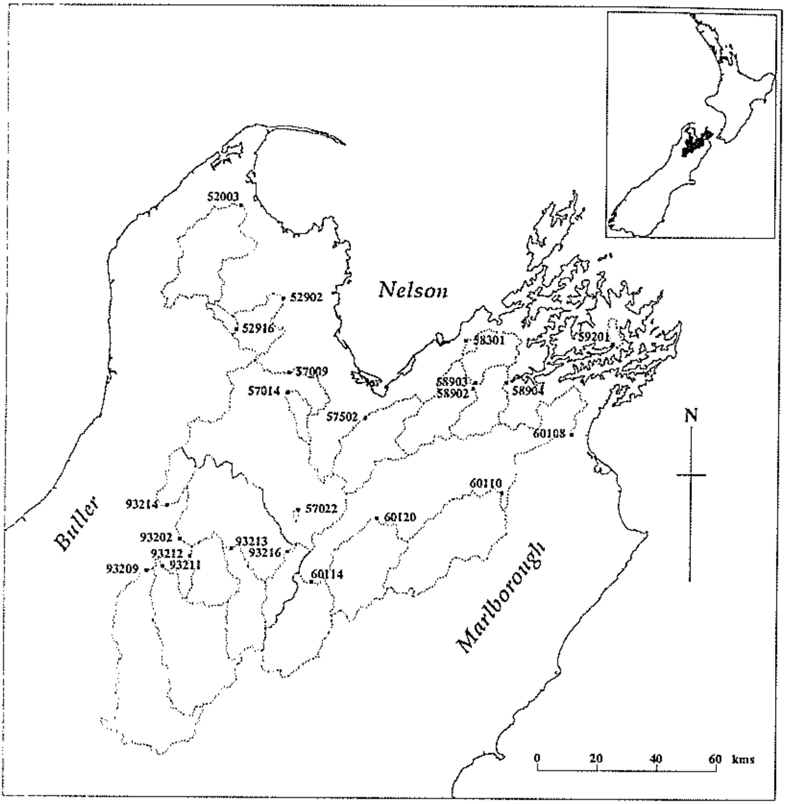

FIG. 4—Location of 23 Nelson (South Island) Water Resources Survey gauging stations (squares, with upstream drainage basin boundaries) used for the NAUGLS study.

than the North Island plot (Fig. 2) but no unusual outliers. For the low-flow equation, the Buller sites (prefixed 932 in Table 3) tended to have positive residuals, while other sites in the region tended to have negative residuals. Residuals for the mean flow equation appeared randomly scattered. For the flood peak equation, the Buller sites tended to have negative residuals and other sites in the region tended to be positive. Therefore, the Nelson region appears to be hydrologically heterogeneous. Hutchinson (1990; low flows), Mosley (1981; floods) and Beable and McKerchar (1982; floods) all split the Nelson region (Fig. 4) into three regions. However, for the purpose of illustration, the Nelson Water Resources Survey region was assumed to be hydrologically homogeneous.

NAUGLS Results

NAUGLS was run for low, mean and peak flows, and for four planning horizons (5, 10, 20 and 40 years). In each experiment, the 22 existing sites and 1 new site were reduced to 16 sites during the planning horizon. NAUGLS dropped

TABLE 4—NAUGLS results for Nelson Water Resources Survey water-level recording network. Sites are listed in order of least influence on improving the precision of each regional equation.

Planning Horizon (years)	Low Flow	Mean Flow	Peak Flow
5	93213	93213	93213
	93209	93212	93212
	93211	93209	93209
	93212	93211	93211
	93214	93214	93214
	58902	58902	58301
	58301	58301	58902
10	93213	93213	93213
	93209	93212	93212
	93211	93209	93209
	93212	93211	93211
	93214	93214	93214
	58902	58902	58902
	58301	58301	58301
20	93213	93213	93213
	93209	93212	93212
	93211	93209	93209
	93212	93211	93211
	93214	93214	93214
	58902	58902	58902
	58301	58301	58301
40	93213	93213	93213
	93209	93214	93212
	93211	93209	93214
	93214	93212	93209
	93212	93211	93211
	58902	58902	58902
	58301	58301	58301

the 7 sites eligible for closure in order of least influence on improving the precision of each regional equation. The results of each experiment are listed in Table 4.

In each experiment, site 93213 was the first to be dropped, i.e. its continued operation during the planning horizon would least improve the precision of each regional equation. This is not surprising since 93213 has a much longer record than those of the other sites eligible for closure. NAUGLS balances spatial and temporal information, and decided, in this case, that more could be learned about the region by continued operation of other sites with shorter records than by extending the longest record site.

Once the closed site 93212 is taken from the NAUGLS results table (Table 4), the order of closing sites is best summarised as 93213, 93209, 93211, 93214,

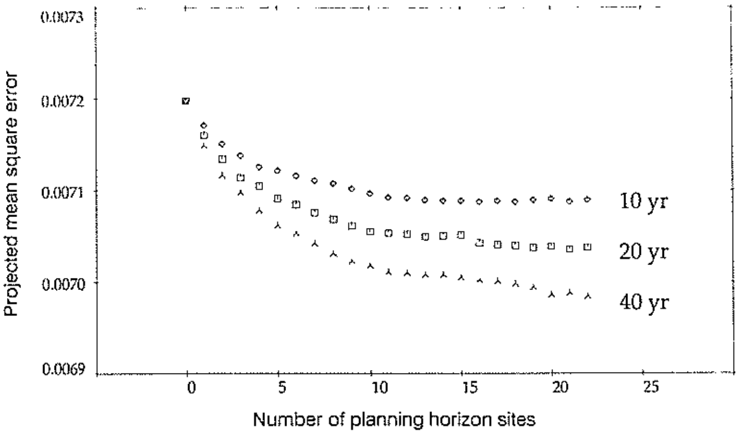

FIG. 5—NAUGLS projected sampling mean square error (in log units) for Nelson mean flows plotted against the number of existing sites operating over planning horizons of 10, 20 and 40 years.

58902, 58301. This conclusion is valid only in terms of the regional importance of sites for low, mean and peak flows. Other criteria, such as data quality, might also be considered by the network managers. For floods, the ratio of maximum current-meter gauged water level to maximum recorded water level is a good indicator of data quality (Potter and Walker, 1985).

DISCUSSION

The Nelson example highlighted NAUGLS's use when future network spending is to decrease. When budgets are less restrictive, the effects on regional equation precision of opening new sites can be monitored by NAUGLS: a ranked list is produced containing both existing and new sites in order of least importance to regional equation precision (see e.g. Tasker, 1986).

NAUGLS results can be plotted to show projected reduction in sampling mean square error as more sites are operated in a planning horizon. For example, Figure 5 shows projected reduction in sampling mean square error for mean flows of 22 existing Nelson sites and planning horizons of 10, 20 and 40 years. To achieve precision of say 0.0071 (log units) 10 sites could be operated for the next 10 years, 5 sites for 20 years or 2 sites for 40 years.

For both North Island and particularly for Nelson, the hydrological homogeneity of the network analyses region was found to be questionable. The assumption of regional homogeneity probably is essential for network design aids to find optimum strategies. However in regions with mild heterogeneity, e.g., where discharge variables change gradually with distance (e.g. McKerchar and Pearson, 1990, New Zealand flood contour maps), NAUGLS still should provide useful results for network managers, even though the underlying regression equation might be too imprecise for use.

The main conclusion from the HYNET study using New Zealand data was that NAUGLS provided superior hydrological network analysis for North Island mean flows.

APPENDIX 1

North Island water-level recording sites used for HYNET – 76 sites with complete records over the period 1971–1990. Mean discharges were calculated over this period.

Site Number	River	Area (km^2)	Annual Rain (mm)	Mean (m^3/s)
1316	Awanui at School Cut	220	1770	6.10
3506	Maungaparerua at Tyrees Ford	11.1	2320	0.463
4901	Ngunguru at Dugmores Rock	12.5	1900	0.419
7604	Wairau at Motorway	11.1	1290	0.243
9140	Piako at Paeroa Tahuna Rd Br	534	1150	6.75
9205	Waihou at Te Aroha Br	1130	1460	41.9
9213	Ohinemuri at Karangahake	305	1790	12.9
9301	Kauaeranga at Smiths	121	2000	6.55
14628	Mangorewa at Saunders Farm	185	2370	6.17
15408	Rangitaiki at Murupara	1140	1560	21.0
15410	Whirinaki at Galatea	509	1590	14.3
15511	Waimana at Waimana Gorge	467	2240	17.0
15514	Whakatane at Whakatane	1560	2020	54.4
15534	Wairere at Wainui Rd	2.67	1320	0.0371
15536	Waimana at Ogilvies Br	206	2420	7.88
15901	Waioeka at Gorge Cable	662	2370	32.3
16501	Motu at Houpoto	1380	2000	88.0
16502	Motu at Waitangirua	293	2120	13.0
19716	Waipaoa at Kanakanaia C/W	1570	1420	32.4
21409	Waiau at Otoi	534	2030	21.2
21410	Waihi at Waihi	50.2	2020	2.00
21801	Mohaka at Raupunga	2370	2000	79.7
21803	Mohaka at Glenfalls	1040	2110	38.0
22802	Esk at Waipunga Br	253	1570	5.83
2305	Ngahere at Ngahere Wei	0.521	2600	0.0292
23104	Ngaruroro at Kuripapango	385	2600	17.0
23201	Tukituki at Red Br	2380	1200	45.4
23209	Otane at Glendon	23.3	900	0.168
23210	Omakere at Fordale	53.7	1390	1.04
25902	Whareama at Waiteko	400	1200	6.46
29201	Ruamahanga at Wardells	640	1540	24.1
29202	Ruamahanga at Waihenga	2340	1200	84.5
29224	Waiohine at Gorge	184	4250	30.4
29231	Taueru at Te Weraiti	398	1100	6.34
29242	Atiwhakatu at Mt Holdsworth	40.2	2520	3.52
29244	Whangaehu at Waihi	36.3	1240	0.559
29250	Ruakokopatuna at Iraia	15.5	1950	0.711

Site Number	River	Area (km^2)	Annual Rain (mm)	Mean (m^3/s)
29808	Hutt at Kaitoke	87.2	3210	7.75
29818	Hutt at Birchville	426	2390	22.1
30516	Mill Ck at Papanui	9.10	1180	0.140
30701	Porirua at Town Centre	44.6	1260	0.733
32531	Mangatainoka at Suspension	406	1880	16.3
32563	Oroua at Kawa Wool	575	1380	11.1
1032560	Manawatu at Teachers College	3910	1500	105
32702	Rangitikei at Mangaweka	2690	1500	62.9
33107	Whangaehu at Karioi	471	2170	14.2
33111	Mangawhero at Ore Ore	511	1620	13.4
33114	Waitangi at Tangiwai	53.1	1360	1.01
33115	Mangaetoroa at School	32.7	1520	0.888
33117	Makotuku at SH49A Br	20.6	2390	0.870
33301	Wanganui at Paetawa	6640	1500	221
33302	Wanganui at Te Maire	2210	2100	85.9
33316	Ongarue at Taringamutu	1080	1700	33.3
33320	Whakapapa at Footbridge	173	3170	15.2
33347	Wanganui at Te Porere	27.1	2990	1.33
33356	Wanganui at Piriaka	841	2510	42.8
36001	Punehu at Pihama	30.9	2490	1.15
39501	Waitara at Tarata	705	2370	33.2
43433	Waipa at Whatawhata	2820	1560	87.3
43435	Waipapa at Ngaroma Rd	134	1760	5.66
43472	Waiotapu at Reporoa	232	1480	3.71
1043419	Pokaiwhenua at Puketurua	430	1500	4.99
1043427	Mangakino at Dillon Rd	342	1610	10.8
1043428	Tahunaatara at Ohakuri Rd	195	1550	4.50
1043434	Mangakara at Hirsts	21.5	1570	0.376
1043459	Tongariro at Turangi	772	2600	34.4
1043460	Tongariro at Puketara	503	2930	24.1
1043461	Tongariro at Upper Dam	182	3030	11.3
1043466	Waihohonu at Desert Rd	95.8	3170	5.97
1143409	Purukohukohu at Puruki	0.344	1700	0.00536
1143428	Ohote at Rotokauri	14.6	1390	0.290
1443495	Tongariro at Rangipo Barrage	216	3080	16.2
43602	Waitangi at SHBr	17.8	1380	0.236
45702	Waiwhiu at Dome Shadow	8.20	1770	0.279
46618	Mangakahia at Gorge	244	2000	10.1
47527	Opahi at Pond	10.0	1760	0.253

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