Input Data : Naradaw P= 1,600 kW

Year of Start (n=0) 1997

(Thousand M$)

| | n | Year | Naradaw Invest. | Diesel Invest. | Diesel kWh | Year |
|---|---|---|---|---|---|---|
| Const. | 0 | 1997 | 1,150 | 0 | | 1997 |
| Const. | 1 | 1998 | 6,900 | 488 | | 1998 |
| Const. | 2 | 1999 | 3,450 | 488 | | 1999 |
| Opera. | 3 | 2000 | 173 | 49 | 4,806 | 2000 |
| Opera. | 4 | 2001 | | | 5,446 | 2001 |
| Opera. | 5 | 2002 | | | 6,117 | 2002 |
| Opera. | 6 | 2003 | | | 6,802 | 2003 |
| Opera. | 7 | 2004 | | | 7,437 | 2004 |
| Opera. | 8 | 2005 | | | 8,044 | 2005 |
| Opera. | 9 | 2006 | | | 8,437 | 2006 |
| Opera. | 10 | 2007 | | | 8,733 | 2007 |
| Opera. | 11 | 2008 | | | 8,968 | 2008 |
| Opera. | 12 | 2009 | | | 9,157 | 2009 |
| Opera. | 13 | 2010 | | | 9,337 | 2010 |
| Opera. | 14 | 2011 | | | 9,420 | 2011 |
| Opera. | 15 | 2012 | | 49 | 9,491 | 2012 |
| Re-Const | 16 | 2013 | | 488+49 | 9,555 | 2013 |
| Re-Const | 17 | 2014 | | 488+49 | 9,608 | 2014 |
| Opera. | 18 | 2015 | | 49 | 9,649 | 2015 |
| Opera. | 19 | 2016 | | | 9,691 | 2016 |
| Opera. | 20 | 2017 | | | 9,691 | 2017 |
| Opera. | 21 | 2018 | | | 9,691 | 2018 |
| Opera. | 22 | 2019 | | | 9,691 | 2019 |
| Opera. | 23 | 2020 | | | 9,691 | 2020 |
| Opera. | 24 | 2021 | | | 9,691 | 2021 |
| Opera. | 25 | 2022 | | | 9,691 | 2022 |
| Opera. | 26 | 2023 | | | 9,691 | 2023 |
| Opera. | 27 | 2024 | 173 | 49 | 9,691 | 2024 |

Benefit Cost Ratio Calculation : Naradaw P= 1,600 kW

*In Case of Carabau 2X1000KW*

(Thousand M$)

| Year | n | 1/1.1 n | Cost Stream Naradaw Invest. | Cost Stream Naradaw C Value | Benefit Stream Alternative (Diesel) Invest. | Benefit Stream Alternative (Diesel) Fuel | Benefit Stream Alternative (Diesel) Total | B Value |
|---|---|---|---|---|---|---|---|---|
| 1997 | 0 | 1.000 | 1,150 | 1,150 | 0 | 0 | 0 | 0 |
| 1998 | 1 | 0.909 | 6,900 | 6,273 | 488 | 0 | 488 | 444 |
| 1999 | 2 | 0.826 | 3,450 | 2,851 | 488 | 0 | 488 | 403 |
| 2000 | 3 | 0.751 | 173 | 130 | 49 | 841 | 890 | 669 |
| 2001 | 4 | 0.683 | 173 | 118 | 49 | 953 | 1,002 | 684 |
| 2002 | 5 | 0.621 | 173 | 107 | 49 | 1,070 | 1,119 | 695 |
| 2003 | 6 | 0.564 | 173 | 98 | 49 | 1,190 | 1,239 | 700 |
| 2004 | 7 | 0.513 | 173 | 89 | 49 | 1,301 | 1,350 | 693 |
| 2005 | 8 | 0.467 | 173 | 81 | 49 | 1,408 | 1,457 | 680 |
| 2006 | 9 | 0.424 | 173 | 73 | 49 | 1,476 | 1,525 | 647 |
| 2007 | 10 | 0.386 | 173 | 67 | 49 | 1,528 | 1,577 | 608 |
| 2008 | 11 | 0.350 | 173 | 61 | 49 | 1,569 | 1,618 | 567 |
| 2009 | 12 | 0.319 | 173 | 55 | 49 | 1,602 | 1,651 | 526 |
| 2010 | 13 | 0.290 | 173 | 50 | 49 | 1,634 | 1,683 | 487 |
| 2011 | 14 | 0.263 | 173 | 46 | 49 | 1,649 | 1,698 | 447 |
| 2012 | 15 | 0.239 | 173 | 41 | 49 | 1,661 | 1,710 | 409 |
| 2013 | 16 | 0.218 | 173 | 38 | 537 | 1,672 | 2,209 | 481 |
| 2014 | 17 | 0.198 | 173 | 34 | 537 | 1,681 | 2,218 | 439 |
| 2015 | 18 | 0.180 | 173 | 31 | 49 | 1,689 | 1,738 | 313 |
| 2016 | 19 | 0.164 | 173 | 28 | 49 | 1,696 | 1,745 | 285 |
| 2017 | 20 | 0.149 | 173 | 26 | 49 | 1,696 | 1,745 | 259 |
| 2018 | 21 | 0.135 | 173 | 23 | 49 | 1,696 | 1,745 | 236 |
| 2019 | 22 | 0.123 | 173 | 21 | 49 | 1,696 | 1,745 | 214 |
| 2020 | 23 | 0.112 | 173 | 19 | 49 | 1,696 | 1,745 | 195 |
| 2021 | 24 | 0.102 | 173 | 18 | 49 | 1,696 | 1,745 | 177 |
| 2022 | 25 | 0.092 | 173 | 16 | 49 | 1,696 | 1,745 | 161 |
| 2023 | 26 | 0.084 | 173 | 15 | 49 | 1,696 | 1,745 | 146 |
| 2024 | 27 | 0.076 | 173 | 13 | 49 | 1,696 | 1,745 | 133 |
| | | Total | | 11,572 | | | | 11,699 |

| | |
|---|---|
| B/C | 1.01 |
| B-C | 128 |

Input Data : Naradaw P= 1.600 kW

Year of Start (n=0) 1993

(Thousand M$)

| | n | Year | Naradaw Invest. | Diesel Invest. | Diesel kWh | Year |
|---|---|---|---|---|---|---|
| Const. | 0 | 1993 | 1.150 | 0 | | 1993 |
| Const. | 1 | 1994 | 6.900 | 488 | | 1994 |
| Const. | 2 | 1995 | 3.450 | 488 | | 1995 |
| Opera. | 3 | 1996 | 173 | 49 | 3.785 | 1996 |
| Opera. | 4 | 1997 | | | 4.628 | 1997 |
| Opera. | 5 | 1998 | | | 5.507 | 1998 |
| Opera. | 6 | 1999 | | | 6.390 | 1999 |
| Opera. | 7 | 2000 | | | 7.351 | 2000 |
| Opera. | 8 | 2001 | | | 7.999 | 2001 |
| Opera. | 9 | 2002 | | | 8.471 | 2002 |
| Opera. | 10 | 2003 | | | 8.796 | 2003 |
| Opera. | 11 | 2004 | | | 9.044 | 2004 |
| Opera. | 12 | 2005 | | | 9.256 | 2005 |
| Opera. | 13 | 2006 | | | 9.407 | 2006 |
| Opera. | 14 | 2007 | | | 9.532 | 2007 |
| Opera. | 15 | 2008 | | 49 | 9.631 | 2008 |
| Re-Const | 16 | 2009 | | 488+49 | 9.691 | 2009 |
| Re-Const | 17 | 2010 | | 488+49 | 9.691 | 2010 |
| Opera. | 18 | 2011 | | 49 | 9.691 | 2011 |
| Opera. | 19 | 2012 | | | 9.691 | 2012 |
| Opera. | 20 | 2013 | | | 9.691 | 2013 |
| Opera. | 21 | 2014 | | | 9.691 | 2014 |
| Opera. | 22 | 2015 | | | 9.691 | 2015 |
| Opera. | 23 | 2016 | | | 9.691 | 2016 |
| Opera. | 24 | 2017 | | | 9.691 | 2017 |
| Opera. | 25 | 2018 | | | 9.691 | 2018 |
| Opera. | 26 | 2019 | | | 9.691 | 2019 |
| Opera. | 27 | 2020 | 173 | 49 | 9.691 | 2020 |

Benefit Cost Ratio Calculation : Naradaw P= 1.600 kW

In case of Carabau 1 × 1000 kW

(Thousand M$)

| Year | n | 1/1.1^n | Cost Stream Naradaw Invest. | Cost Stream Naradaw C Value | Benefit Stream Alternative (Diesel) Invest. | Fuel | Total | B Value |
|---|---|---|---|---|---|---|---|---|
| 1993 | 0 | 1.000 | 1.150 | 1.150 | 0 | 0 | 0 | 0 |
| 1994 | 1 | 0.909 | 6.900 | 6.273 | 488 | 0 | 488 | 444 |
| 1995 | 2 | 0.826 | 3.450 | 2.851 | 488 | 0 | 488 | 403 |
| 1996 | 3 | 0.751 | 173 | 130 | 49 | 662 | 711 | 534 |
| 1997 | 4 | 0.683 | 173 | 118 | 49 | 810 | 859 | 587 |
| 1998 | 5 | 0.621 | 173 | 107 | 49 | 964 | 1.013 | 629 |
| 1999 | 6 | 0.564 | 173 | 98 | 49 | 1.118 | 1.167 | 659 |
| 2000 | 7 | 0.513 | 173 | 89 | 49 | 1.286 | 1.335 | 685 |
| 2001 | 8 | 0.467 | 173 | 81 | 49 | 1.400 | 1.449 | 676 |
| 2002 | 9 | 0.424 | 173 | 73 | 49 | 1.482 | 1.531 | 649 |
| 2003 | 10 | 0.386 | 173 | 67 | 49 | 1.539 | 1.588 | 612 |
| 2004 | 11 | 0.350 | 173 | 61 | 49 | 1.583 | 1.632 | 572 |
| 2005 | 12 | 0.319 | 173 | 55 | 49 | 1.620 | 1.669 | 532 |
| 2006 | 13 | 0.290 | 173 | 50 | 49 | 1.646 | 1.695 | 491 |
| 2007 | 14 | 0.263 | 173 | 46 | 49 | 1.668 | 1.717 | 452 |
| 2008 | 15 | 0.239 | 173 | 41 | 49 | 1.685 | 1.734 | 415 |
| 2009 | 16 | 0.218 | 173 | 38 | 537 | 1.696 | 2.233 | 486 |
| 2010 | 17 | 0.198 | 173 | 34 | 537 | 1.696 | 2.233 | 442 |
| 2011 | 18 | 0.180 | 173 | 31 | 49 | 1.696 | 1.745 | 314 |
| 2012 | 19 | 0.164 | 173 | 28 | 49 | 1.696 | 1.745 | 285 |
| 2013 | 20 | 0.149 | 173 | 26 | 49 | 1.696 | 1.745 | 259 |
| 2014 | 21 | 0.135 | 173 | 23 | 49 | 1.696 | 1.745 | 236 |
| 2015 | 22 | 0.123 | 173 | 21 | 49 | 1.696 | 1.745 | 214 |
| 2016 | 23 | 0.112 | 173 | 19 | 49 | 1.696 | 1.745 | 195 |
| 2017 | 24 | 0.102 | 173 | 18 | 49 | 1.696 | 1.745 | 177 |
| 2018 | 25 | 0.092 | 173 | 16 | 49 | 1.696 | 1.745 | 161 |
| 2019 | 26 | 0.084 | 173 | 15 | 49 | 1.696 | 1.745 | 146 |
| 2020 | 27 | 0.076 | 173 | 13 | 49 | 1.696 | 1.745 | 133 |
| | | Total | | 11.572 | | | | 11.390 |

B/C 0.98

B-C -182

Input Data : Naradaw P= 1,600 kW

Year of Start (n=0) 1994

(Thousand M$)

| | n | Year | Naradaw Invest. | Diesel Invest. | Diesel kWh | Year |
|---|---|---|---|---|---|---|
| Const. | 0 | 1994 | 1,150 | 0 | | 1994 |
| Const. | 1 | 1995 | 6,900 | 488 | | 1995 |
| Const. | 2 | 1996 | 3,450 | 488 | | 1996 |
| Opera. | 3 | 1997 | 173 | 49 | 4,628 | 1997 |
| Opera. | 4 | 1998 | | | 5,507 | 1998 |
| Opera. | 5 | 1999 | | | 6,390 | 1999 |
| Opera. | 6 | 2000 | | | 7,351 | 2000 |
| Opera. | 7 | 2001 | | | 7,999 | 2001 |
| Opera. | 8 | 2002 | | | 8,471 | 2002 |
| Opera. | 9 | 2003 | | | 8,796 | 2003 |
| Opera. | 10 | 2004 | | | 9,044 | 2004 |
| Opera. | 11 | 2005 | | | 9,256 | 2005 |
| Opera. | 12 | 2006 | | | 9,407 | 2006 |
| Opera. | 13 | 2007 | | | 9,532 | 2007 |
| Opera. | 14 | 2008 | | | 9,631 | 2008 |
| Opera. | 15 | 2009 | | 49 | 9,691 | 2009 |
| Re-Const | 16 | 2010 | | 488+49 | 9,691 | 2010 |
| Re-Const | 17 | 2011 | | 488+49 | 9,691 | 2011 |
| Opera. | 18 | 2012 | | 49 | 9,691 | 2012 |
| Opera. | 19 | 2013 | | | 9,691 | 2013 |
| Opera. | 20 | 2014 | | | 9,691 | 2014 |
| Opera. | 21 | 2015 | | | 9,691 | 2015 |
| Opera. | 22 | 2016 | | | 9,691 | 2016 |
| Opera. | 23 | 2017 | | | 9,691 | 2017 |
| Opera. | 24 | 2018 | | | 9,691 | 2018 |
| Opera. | 25 | 2019 | | | 9,691 | 2019 |
| Opera. | 26 | 2020 | | | 9,691 | 2020 |
| Opera. | 27 | 2021 | 173 | 49 | 9,691 | 2021 |

Benefit Cost Ratio Calculation : Naradaw P= 1,600 kW

*In case of Carabau 1 × 1000 kW*

(Thousand M$)

| Year | n | 1/1.1^n | Cost Stream Naradaw Invest. | Cost Stream Naradaw C Value | Benefit Stream Alternative (Diesel) Invest. | Fuel | Total | B Value |
|---|---|---|---|---|---|---|---|---|
| 1994 | 0 | 1.000 | 1,150 | 1,150 | 0 | 0 | 0 | 0 |
| 1995 | 1 | 0.909 | 6,900 | 6,273 | 488 | 0 | 488 | 444 |
| 1996 | 2 | 0.826 | 3,450 | 2,851 | 488 | 0 | 488 | 403 |
| 1997 | 3 | 0.751 | 173 | 130 | 49 | 810 | 859 | 645 |
| 1998 | 4 | 0.683 | 173 | 118 | 49 | 964 | 1,013 | 692 |
| 1999 | 5 | 0.621 | 173 | 107 | 49 | 1,118 | 1,167 | 725 |
| 2000 | 6 | 0.564 | 173 | 98 | 49 | 1,286 | 1,335 | 754 |
| 2001 | 7 | 0.513 | 173 | 89 | 49 | 1,400 | 1,449 | 743 |
| 2002 | 8 | 0.467 | 173 | 81 | 49 | 1,482 | 1,531 | 714 |
| 2003 | 9 | 0.424 | 173 | 73 | 49 | 1,539 | 1,588 | 674 |
| 2004 | 10 | 0.386 | 173 | 67 | 49 | 1,583 | 1,632 | 629 |
| 2005 | 11 | 0.350 | 173 | 61 | 49 | 1,620 | 1,669 | 585 |
| 2006 | 12 | 0.319 | 173 | 55 | 49 | 1,646 | 1,695 | 540 |
| 2007 | 13 | 0.290 | 173 | 50 | 49 | 1,668 | 1,717 | 497 |
| 2008 | 14 | 0.263 | 173 | 46 | 49 | 1,685 | 1,734 | 457 |
| 2009 | 15 | 0.239 | 173 | 41 | 49 | 1,696 | 1,745 | 418 |
| 2010 | 16 | 0.218 | 173 | 38 | 537 | 1,696 | 2,233 | 486 |
| 2011 | 17 | 0.198 | 173 | 34 | 537 | 1,696 | 2,233 | 442 |
| 2012 | 18 | 0.180 | 173 | 31 | 49 | 1,696 | 1,745 | 314 |
| 2013 | 19 | 0.164 | 173 | 28 | 49 | 1,696 | 1,745 | 285 |
| 2014 | 20 | 0.149 | 173 | 26 | 49 | 1,696 | 1,745 | 259 |
| 2015 | 21 | 0.135 | 173 | 23 | 49 | 1,696 | 1,745 | 236 |
| 2016 | 22 | 0.123 | 173 | 21 | 49 | 1,696 | 1,745 | 214 |
| 2017 | 23 | 0.112 | 173 | 19 | 49 | 1,696 | 1,745 | 195 |
| 2018 | 24 | 0.102 | 173 | 18 | 49 | 1,696 | 1,745 | 177 |
| 2019 | 25 | 0.092 | 173 | 16 | 49 | 1,696 | 1,745 | 161 |
| 2020 | 26 | 0.084 | 173 | 15 | 49 | 1,696 | 1,745 | 146 |
| 2021 | 27 | 0.076 | 173 | 13 | 49 | 1,696 | 1,745 | 133 |
| | | Total | | 11,572 | | | | 11,969 |

| | |
|---|---|
| B/C | 1.03 |
| B-C | 397 |

Input Data : Naradaw P= 1.600 kW

Year of Start (n=0) 1997

(Thousand M$)

| | n | Year | Naradaw Invest. | Diesel Invest. | Diesel kWh | Year |
|---|---|---|---|---|---|---|
| Const. | 0 | 1997 | 1.150 | 0 | | 1997 |
| Const. | 1 | 1998 | 6.900 | 488 | | 1998 |
| Const. | 2 | 1999 | 3.450 | 488 | | 1999 |
| Opera. | 3 | 2000 | 173 | 49 | 7.351 | 2000 |
| Opera. | 4 | 2001 | | | 7.999 | 2001 |
| Opera. | 5 | 2002 | | | 8.471 | 2002 |
| Opera. | 6 | 2003 | | | 8.796 | 2003 |
| Opera. | 7 | 2004 | | | 9.044 | 2004 |
| Opera. | 8 | 2005 | | | 9.256 | 2005 |
| Opera. | 9 | 2006 | | | 9.407 | 2006 |
| Opera. | 10 | 2007 | | | 9.532 | 2007 |
| Opera. | 11 | 2008 | | | 9.631 | 2008 |
| Opera. | 12 | 2009 | | | 9.691 | 2009 |
| Opera. | 13 | 2010 | | | 9.691 | 2010 |
| Opera. | 14 | 2011 | | | 9.691 | 2011 |
| Opera. | 15 | 2012 | | 49 | 9.691 | 2012 |
| Re-Const | 16 | 2013 | | 488 + 49 | 9.691 | 2013 |
| Re-Const | 17 | 2014 | | 488 + 49 | 9.691 | 2014 |
| Opera. | 18 | 2015 | | 49 | 9.691 | 2015 |
| Opera. | 19 | 2016 | | | 9.691 | 2016 |
| Opera. | 20 | 2017 | | | 9.691 | 2017 |
| Opera. | 21 | 2018 | | | 9.691 | 2018 |
| Opera. | 22 | 2019 | | | 9.691 | 2019 |
| Opera. | 23 | 2020 | | | 9.691 | 2020 |
| Opera. | 24 | 2021 | | | 9.691 | 2021 |
| Opera. | 25 | 2022 | | | 9.691 | 2022 |
| Opera. | 26 | 2023 | | | 9.691 | 2023 |
| Opera. | 27 | 2024 | 173 | 49 | 9.691 | 2024 |

Benefit Cost Ratio Calculation : Naradaw P= 1.600 kW

In case of Carabau 1 x 1000 kW

(Thousand M$)

| Year | n | 1/1.1^n | Cost Stream Naradaw Invest. | Cost Stream Naradaw C Value | Benefit Stream Alternative (Diesel) Invest. | Fuel | Total | B Value |
|---|---|---|---|---|---|---|---|---|
| 1997 | 0 | 1.000 | 1.150 | 1.150 | 0 | 0 | 0 | 0 |
| 1998 | 1 | 0.909 | 6.900 | 6.273 | 488 | 0 | 488 | 444 |
| 1999 | 2 | 0.826 | 3.450 | 2.851 | 488 | 0 | 488 | 403 |
| 2000 | 3 | 0.751 | 173 | 130 | 49 | 1.286 | 1.335 | 1.003 |
| 2001 | 4 | 0.683 | 173 | 118 | 49 | 1.400 | 1.449 | 990 |
| 2002 | 5 | 0.621 | 173 | 107 | 49 | 1.482 | 1.531 | 951 |
| 2003 | 6 | 0.564 | 173 | 98 | 49 | 1.539 | 1.588 | 897 |
| 2004 | 7 | 0.513 | 173 | 89 | 49 | 1.583 | 1.632 | 837 |
| 2005 | 8 | 0.467 | 173 | 81 | 49 | 1.620 | 1.669 | 779 |
| 2006 | 9 | 0.424 | 173 | 73 | 49 | 1.646 | 1.695 | 719 |
| 2007 | 10 | 0.386 | 173 | 67 | 49 | 1.668 | 1.717 | 662 |
| 2008 | 11 | 0.350 | 173 | 61 | 49 | 1.685 | 1.734 | 608 |
| 2009 | 12 | 0.319 | 173 | 55 | 49 | 1.696 | 1.745 | 556 |
| 2010 | 13 | 0.290 | 173 | 50 | 49 | 1.696 | 1.745 | 505 |
| 2011 | 14 | 0.263 | 173 | 46 | 49 | 1.696 | 1.745 | 459 |
| 2012 | 15 | 0.239 | 173 | 41 | 49 | 1.696 | 1.745 | 418 |
| 2013 | 16 | 0.218 | 173 | 38 | 537 | 1.696 | 2.233 | 486 |
| 2014 | 17 | 0.198 | 173 | 34 | 537 | 1.696 | 2.233 | 442 |
| 2015 | 18 | 0.180 | 173 | 31 | 49 | 1.696 | 1.745 | 314 |
| 2016 | 19 | 0.164 | 173 | 28 | 49 | 1.696 | 1.745 | 285 |
| 2017 | 20 | 0.149 | 173 | 26 | 49 | 1.696 | 1.745 | 259 |
| 2018 | 21 | 0.135 | 173 | 23 | 49 | 1.696 | 1.745 | 236 |
| 2019 | 22 | 0.123 | 173 | 21 | 49 | 1.696 | 1.745 | 214 |
| 2020 | 23 | 0.112 | 173 | 19 | 49 | 1.696 | 1.745 | 195 |
| 2021 | 24 | 0.102 | 173 | 18 | 49 | 1.696 | 1.745 | 177 |
| 2022 | 25 | 0.092 | 173 | 16 | 49 | 1.696 | 1.745 | 161 |
| 2023 | 26 | 0.084 | 173 | 15 | 49 | 1.696 | 1.745 | 146 |
| 2024 | 27 | 0.076 | 173 | 13 | 49 | 1.696 | 1.745 | 133 |
| | | Total | | 11.572 | | | | 13.280 |

| | |
|---|---|
| B/C | 1.15 |
| B-C | 1.708 |

# Appendix 5 PERMISSIBLE TRANSMISSION CAPACITY FOR 11 KV EXISTING INTERCONNECTION LINE RANAU-KUNDASANG GRID

**Appendix 5**

# PERMISSIBLE TRANSMISSION CAPACITY FOR 11 KV EXISTING INTERCONNECTION LINE RANAU-KUNDASANG GRID

## CONTENTS

## Permissible Transmission Capacity

## for 11 kV Existing Interconnection Line Ranau-Kundasang Grid

It is to consider a three-phase overhead line 6 miles long, from proposed mini hydro P.P (Naradaw P.P) to Ranau, supplying energy at 11,000 volts with a frequency of 50 Hz.

The conductors consist of No. 0000 B&S., stranded Aluminum, spaced in a horizontal plane with a separation of 2.0 ft. between the center wire and each of the outer wires.

It is desired to calculated the maximum load in kilowatts with the power factor 0.8 which can be transmitted by this line and given that the inherent regulation (or percentage voltage drop) must not exceed 10 percent when the temperature of the wire at circumstances in 90°F.

The calculation was made based on the following conditions:

Voltage between lines at receiving end,

$E = 11{,}000$ volts

Frequency, $f = 50$ Hz

Power factor of load, $\cos \phi = 0.8$

Length of line, $L = 6$ miles

Diameter of No. 0000 stranded conductor

$2r = 0.522$ in

Area of cross-section of wire = 0.1662 sq. in

Resistance, ohms per mile, at 20°C (68°F) = 0.430 Ω

The resistance per mile at 90°C

$R_{90} = R_{20} (1 + at)$ ....... (1)

Where $R_{90}$ = resistance at 90°C

t = temperature rise above initial temperature (20°C)

$R_{20}$ = resistance at the initial temperature (20°C)

$$R_{90} = 0.430 \frac{(390+167)}{(390+68)} = 0.523 \ ohm$$

The increase of resistance due to skin effect need not be taken into account because the product area x frequency is 0.1662 x 50 = 8 (approximately), it is seen that the skin-effect multiplier is so small as to be negligible.

The spacing between wires, in inches are:

a = 24, b = 24, c = 48, and the equivalent spacing is

$$d = \sqrt[3]{24 \times 24 \times 48} = 30.2 \ in.$$

Using this value in formula (1), or for d in formula (2),

$$(IX) = 0.0046 \ fI \log_e \frac{\sqrt[3]{abc}}{r} + 0.000506 \ fI \ ....... (1)$$

Reactive voltage drop (IX) per mile of single conductor

$$= 0.00466 \ fI \log (1.285 \frac{d}{r}) \ ....... (2)$$

$\frac{d}{r} = \frac{30.2}{0.261} = 116$ which may be used in the formula (3)

$$x = 0.00466 \times f \times \log (1.285 \times 116) \ ....... (3)$$

The result is reactance per mile of single conductor, X = 0.506 ohm
The required regulation of percentage voltage drop is

$$100 \times \frac{V - E}{E} \quad \ldots\ldots. \ (4)$$

Where V stands for the voltage between conductors at the sending end of the line. The value (V - E) is equal to $\sqrt{3}$ (Vn - En) where Vn and En are star voltages (conductor to neutral) at the sending and receiving ends, respectively.

If the simplified formula (5) is used,

$$Vn = En + IR \cos \theta + IX \sin \theta \quad \ldots\ldots. \ (5)$$

giving the voltage drop per conductor, the loss of voltage as measured between conductor is

$$(V - E) = \sqrt{3}\ IL\ (R \cos \theta + X \sin \theta)$$

Accordingly, the following formula (6) and (7) are obtained based on

$$I = \frac{W}{\sqrt{3}\ E \cos \theta}$$

$$(V - E) = \frac{WL\ (R \cos \theta + X \sin \theta)}{E \cos \theta}\ volts \quad \ldots\ldots \ (6) \quad (approximately)$$

$$(V - E) + \frac{WL\ (R + X \tan \theta)}{E}\ volts \quad \ldots\ldots. \ (7) \quad (approximately)$$

On the other hand, the percentage voltage drop is as shown below.

$$\frac{100\ (V - E)}{E} = \frac{100\ WL\ (R + X \tan \theta)}{E^2} \quad \ldots\ldots. \ (8)$$

Values for tan θ corresponding to any given power factor (cos θ) may be obtained from trigonometric tables, or following formula

$$\tan\theta = \frac{\sqrt{1-\cos\theta}}{\cos\theta}$$

Applying formula (8) to the solution this particular problem,

$$W = \frac{\textit{percent voltage drop} \times E^2}{100L\ (R + X\tan\theta)} \quad \cdots\cdots\cdots \quad (9)$$

$$= \frac{10 \times (11{,}000)^2}{100 \times 6\ (0.523 + 0.506 \times 0.75)}$$

$$= \underline{\underline{2{,}200\ \text{kW}}}$$

The required answer is that the permissible maximum load at the receiving end is 2,200 kW. A load in excess of this would cause the inherent regulation to be greater than 10 percent.

# Appendix 6 PRELIMINARY DESIGN

# Appendix 6

# PRELIMINARY DESIGN

## CONTENTS

## 6.1 Stability Analysis of Dam

The dam bodies must be checked by making stability computation so that following requirements at any horizontal section and contact face between dambody and bedrock are satisfied against external forces and weight of the dam.

(1) No tensile stress must be produced along the upstream face (The action line of resultant force must pass through the middle third of bottom).

(2) No sliding must be ensured against shear friction force.

(3) Compressive stress at the bottom must not exceed it's allowable limit of the ground. (No settlement)

Above requirements are satisfied with following formula. Typical section of Liwagu dam is studied.

- No tensile

$$C = \left|\frac{\Sigma M}{\Sigma V} - \frac{B}{2}\right| = \left|\frac{78.57}{23.38} - \frac{7.0}{2}\right| = 0.14 \le \frac{B}{6} = \frac{7.0}{6} = 1.17 \qquad \therefore \text{OK}$$

- No sliding

when no earthquake

$$\frac{f \cdot \Sigma V}{\Sigma H} = \frac{0.75 \times 23.38}{12.75} = \frac{17.54}{12.75} = 1.37 \ge 1.2 \qquad \therefore \text{OK}$$

when earthquake

$$\frac{f \cdot \Sigma V}{\Sigma H} = \frac{0.75 \times 23.38}{16.69} = \frac{17.54}{16.69} = 1.05 \ge 1.0 \qquad \therefore \text{OK}$$

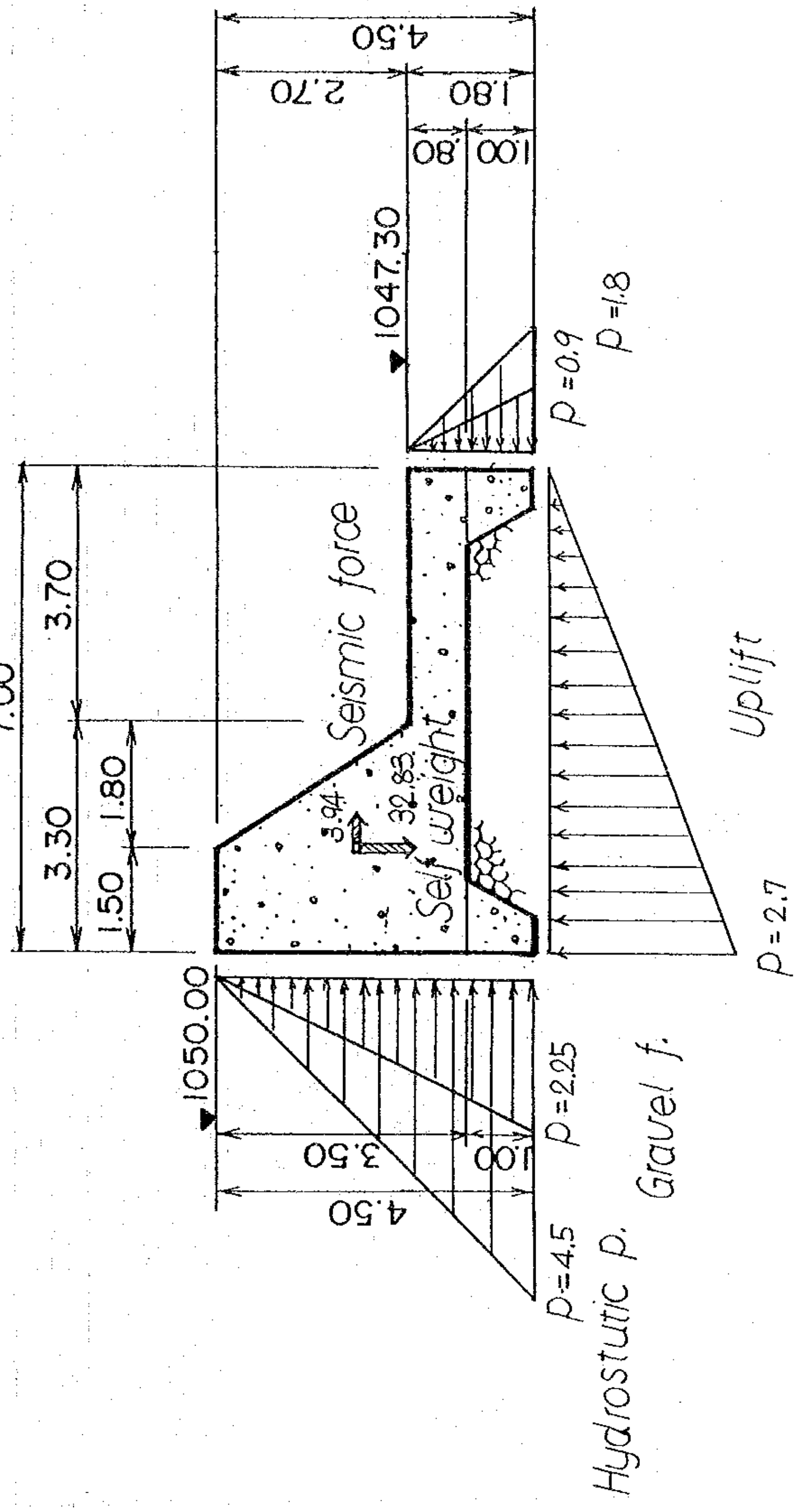
- No settlement

$$\frac{\Sigma V}{B}\left(1 + \frac{6e}{B}\right) = \frac{23.38}{7.0}\left(1 + \frac{6 \times 0.14}{7.0}\right) = 3.74 \le 9a = 50\ ton/m^2 \qquad \therefore \text{OK}$$

**Calculation Sheet**

| Item | External Force (ton) | Arm Length (m) | Moment (t.m) |
|---|---|---|---|
| Self Weight | 13.68 $m^2$ x 2.4= 32.83 | 2.153 | 70.68 |
| Seismic Force | 32.83 x 0.12 = 3.94 | 2.183 | 8.60 |
| Hydrostatic Pressure | $\frac{1}{2}$x4.5x4.5 = 10.12<br>$-\frac{1}{2}$x2.25x4.5 = -1.62 | $\frac{1}{3}$x4.5 = 1.5<br>$\frac{1}{3}$x1.8 = 0.6 | 15.18<br>-0.97 |
| Gravel Force | $\frac{1}{2}$x2.25x4.5 = 5.06<br>$-\frac{1}{2}$x0.9x1.8 = -0.81 | 1.5<br>0.6 | 7.59<br>-0.49 |
| Uplift | $P_1=\frac{1}{3}$x2.7+1.8= 2.7 m<br>$P_2$=0 $m$<br>$-\frac{1}{2}$x2.7x7.0 = -9.45 | $\frac{1}{3}$x7.0 = 2.33 | -22.02 |
| Σ Vertical Force | 32.83-9.45 = 23.38 | $\chi=\frac{78.57}{23.38}$ = 3.36 | 78.57 |
| Σ Horizontal Force with Earthquake | 3.94+10.12-1.62+5.06-0.81 = 16.69 | -- | -- |
| Σ Horizontal F. without Earthquake | 16.69-3.94 = 12.75 | -- | -- |

# SECTION



7.00
3.30
3.70
1.50
1.80
Seismic force
Self weight
3.94
32.83
Uplift
p = 2.7
1050.00
3.50
4.50
1.00
p = 2.25
p = 4.5
Hydrostutic p.
Gravel f.
1047.30
4.50
2.70
1.80
.80
1.00
p = 0.9
p = 1.8

## 6-2 Optimum Diameter of Pipeline

Optimum Diameter of Pipeline at Liwagu Site

| | ITEM | D 1<br>0.5 | D 2<br>0.55 | D 3<br>0.6 | D 4<br>0.65 | D 5<br>0.7 | D 6<br>0.75 |
|---|---|---|---|---|---|---|---|
| Annual Benifit Loss B | Head Loss<br>Δ H (m) | 0.03438 | 0.02068 | 0.013 | 0.00849 | 0.00571 | 0.00396 |
| | Output for Head Loss<br>Δ P (kw) | 0.2005 | 0.1206 | 0.0758 | 0.0495 | 0.0333 | 0.0231 |
| | Energy for Head Loss<br>Δ E (kwh) | 1170.6 | 704.1 | 442.6 | 289.1 | 194.4 | 134.8 |
| | Benifit for Firm Peak<br>Power: B kw(M$) | 47.52 | 28.58 | 17.96 | 11.73 | 7.89 | 5.47 |
| | Benifit for Energy<br>B kwh(M$) | 200.17 | 120.4 | 75.68 | 49.44 | 33.24 | 23.05 |
| | Total Benifit<br>B (M$) | 247.69 | 148.98 | 93.64 | 61.17 | 41.13 | 28.52 |
| Equalized Annual Cost C | Construction Cost<br>C con(M$) | 370 | 420 | 460 | 580 | 710 | 860 |
| | Annual Cost<br>C (M$) | 42.55 | 48.3 | 52.9 | 66.7 | 81.65 | 98.9 |
| Total B + C | B + C (M$) | 290.24 | 197.28 | 146.54 | 127.87 | 122.78 | 127.42 |

Q(m3) = 0.7

n = 0.013

Δ H (m) = 10.298*n^2*Q^2/D^(16/3)

Δ P (kw) = 9.8*η*Q*h

Δ E (kwh) = E*(Q/Qmax)*(Hloss/He) = 9.7*10^6*(Q/1.18)*(Δ H/169)

B kw(M$) = Δ P * Unit kw benifit = 240M$/kw*Δ P

B kwh(M$) = Δ E * Unit kwh benifit = 0.18M$/kwh*Δ E

C (M$) = Annual cost factor * Ccon = 0.115*Ccon

## Optimum Diameter of Pipeline at Mesilau Site

| | ITEM | D1 0.5 | D2 0.55 | D3 0.6 | D4 0.65 | D5 0.7 | D6 0.75 |
|---|---|---|---|---|---|---|---|
| Annual Benifit Loss B | Head Loss ΔH (m) | 0.01617 | 0.00972 | 0.00611 | 0.00399 | 0.00269 | 0.00186 |
| | Output for Head Loss ΔP (kw) | 0.0647 | 0.0389 | 0.0244 | 0.016 | 0.0108 | 0.0074 |
| | Energy for Head Loss ΔE (kwh) | 377.5 | 226.9 | 142.7 | 93.2 | 62.8 | 43.4 |
| | Benifit for Firm Peak Power: B kw(MS) | 15.33 | 9.22 | 5.78 | 3.79 | 2.56 | 1.75 |
| | Benifit for Energy B kwh(MS) | 64.55 | 38.8 | 24.4 | 15.94 | 10.74 | 7.42 |
| | Total Benifit B (MS) | 79.88 | 48.02 | 30.18 | 19.73 | 13.3 | 9.17 |
| Equalized Annual Cost C | Construction Cost C con(MS) | 370 | 420 | 460 | 580 | 710 | 860 |
| | Annual Cost C (MS) | 42.55 | 48.3 | 52.9 | 66.7 | 81.65 | 98.9 |
| Total B + C | B + C (MS) | 122.43 | 96.32 | 83.08 | 86.43 | 94.95 | 108.07 |

Q(m3) = 0.48

n = 0.013

ΔH (m) = 10.298*n^2*Q^2/D^(16/3)

ΔP (kw) = 9.8*η*Q*h

ΔE (kwh) = E*(Q/Qmax)*(Hloss/He) = 9.7*10^6*(Q/1.18)*(ΔH/169)

B kw(MS) = ΔP * Unit kw benifit = 240MS/kw*ΔP

B kwh(MS) = ΔE * Unit kwh benifit = 0.18MS/kwh*ΔE

C (MS) = Annual cost factor * Ccon = 0.115*Ccon

## Calculation of Benefit in terms of Firm Peak Power and Energy (1/1)

| No. | Item | Unit | Calculation | |
|---|---|---|---|---|
| (1) | Firm peak power of Naradaw | MW | 560 kW | |
| (2) | Dependable capacity of Naradaw | MW | (1) × $(1-H_1)\times(1-H_2)\times(1-H_3)$<br>= 560(1-0.01)×(1-0.06)(1-0.10)<br>= 560×0.8375 = 469 kW | |
| (3) | Dependable capacity of Alternative thermal | MW | Same as the value given in (2) | |
| (4) | Rated capacity of Alternative thermal | MW | (3) ÷ $\{(1-T_1)\times(1-T_2)\times(1-T_3)\}$<br>= 469≒(1-0.04)×(1-0.13)×(1-0.20)<br>= 469 ÷ 0.6682 ≒ 700 kW | |
| (5) | Annual energy production of Naradaw | $10^6$ kWh | $9.7 \times 10^6$ kWh | |
| (6) | Available Energy of Naradaw | $10^6$ kWh | (5) × $(1-H_1)$ = 9.7 × (1-0.01)<br>= $9.6 \times 10^6$ kWh | |
| (7) | Available Energy of Alternative thermal | $10^6$ kWh | Same as the value given in (6) | |
| (8) | Annual energy production of Alternative thermal | $10^6$ kWh | (7) ÷ $(1-T_1)$<br>= $9.6 \times 10^6 \div (1-0.04)$<br>= $10.0 \times 10^6$ kWh | |
| | Loss Rates of Hydro and Thermal | | Hydro Power | Thermal Power |
| | Station Service Rate | % | $H_1$ = 1% | $T_1$ = 4% |
| | Outage Rate | % | $H_2$ = 6% | $T_2$ = 13% |
| | Capacity Derated Rate | % | $H_3$ = 10% | $T_3$ = 20% |

## Calculation of Benefit in terms of Firm Peak Power and Energy (1/2)

| | | | | |
|---|---|---|---|---|
| (9) | Fuel Consumption per kWh | | 0.354 ℓ/kWh | |
| (10) | Fuel Cost per Liter | | 0.50 M$/ℓ | |
| (11) | Construction Cost per kW | $/kW | 1,395 M$/kW | |
| (12) | Construction Cost | $10^6$$ | $1,395 \times 700 = 976 \times 10^3$ M$ | |
| (13) | Service Life | year | n = 15 years | |
| (14) | Annual Interest Rate | % | i = 10% | |
| (15) | Capital Recovery Factor | | $\{i(1+i)^n\} \div \{(1+i)^n-1\}$<br>$= \{0.1(1+0.1)^{1.5}\} \div \{(1+0.1)^{15}-1\}$<br>$= 0.13$ | |
| (16) | Rate of O&M Cost to Construction Cost | % | 5% | |
| | | | Fixed Cost | Variable cost |
| (17) | Interest & Depreciation | | (12)×(15)<br>$=127\times10^3$M$ | -- |
| (18) | O&M Cost | | (12)×(16)×0.8<br>$=39\times10^3$M$ | (12)×(16)×0.2<br>$=10\times10^3$M$ |
| (19) | Fuel Cost | | -- | (8)×(9)×(10)<br>$= 1.698\times10^3$M$ |
| (20) | Total of Fixed Cost | | (17)+(18)<br>$=166\times10^3$M$ | -- |
| (21) | Total of variable Cost | | -- | (18)+(19)<br>$=1.708\times10^3$M$ |
| (22) | Benefit Corresponding to Firm Peak Power | $/kW | (20)÷(4)<br>=237≒240M$/kWh | -- |
| (23) | Benefit Corresponding to Energy | $/kW | -- | (21)÷(8)<br>=0.171≒0.18M$/kWh |

## 6-3 Water Hammer Calculation

| | |
|---|---|
| Gross head | 195 |
| Discharge | 0.7 |
| Liwagu | |

WATER HAMMER

1. PRESSURE WAVE VELOCITY

$$a = 1/(w/g*(1/K+D/E/t))^{0.5}$$

Where,

a : Pressure wave velocity (m/sec)
w : Unit weight of water (1.0 tonf/m3)
g : Accelation of gravity (9.8 m/sec2)
K : Bulk modulus of compressibility of water (2.07 x 10^5 tonf/m2)
E : Young's modulus of elasticity for pipe material (for steel pipe = 2.1 x 10^7 tonf/m2)

D : Diameter of pipe (m)
t : Pipe wall thickness (m)

| | D (m) | t (m) | a (m/sec) | Length (m) |
|---|---|---|---|---|
| Liwagu pipeline | 0.7 | 0.006 | 971.4 | 2680.0 |
| Penstock | 0.8 | 0.006 | 936.2 | 456.3 |
| - do - | 0.8 | 0.007 | 976.7 | 120.4 |
| - do - | 0.8 | 0.008 | 1010.7 | 90.3 |
| - do - | 0.8 | 0.009 | 1039.8 | 98.1 |
| - do - | 0.5 | 0.006 | 1055.3 | 15.0 |
| | | | | 3460.1 |

$$a = L/(L1/a1+L2/a2 \cdots Ln/an)$$
$$= 969.877 \text{ m/sec}$$

2. Water Hammer caused by the rapid closing of valve (in the case T < 2*L/a = 7.14 sec)

$$H-Ho = - a/g*(V-Vo)$$

Where, Ho : Water head in constant flowing situation (m)
Vo : Flow velocity in constant flowing situation (m)
H : Water head at a given time after the valve is operated (m)
V : Flow velocity at a given time after the valve is operated (m)

When valve is fully closed and V = 0, H-Ho =a*Vo/g is maximum additional head caused by water hammering.

In case of

Discharge in the pipeline : 0.70 m3/sec,
Mean velocity in the pipeline : 1.724 m/sec

Maximum additional head by water hammer is

H - Ho = 170.619 m

3. Simplified method of calculations for water hammer caused by slowly closing a valve
(in the case T > 2*L/a = 7.16 sec)

This formula is based on the assumption that from the time the first reflective returns to the valve until it is fully closed, the pressure remains unchanged and that the effective opening area of the valve is changed rectilinearly.

H/Ho = 1+n/2*(n+-(n^2+4)^0.5)

In this formula, + causes rise of the pressure at the time of closing the valve, whereas, - causes drop at the time of opening.

n = L*Vo/(T*g*Ho)

Where, T : Time of valve closing (sec)
L : Length of pipeline : 3460.1 (m)
Ho : 195 (m)
Vo : 1.724 (m/sec)

| Time (sec) | n | H (m) (closing) | H (m) (opening) |
|---|---|---|---|
| 10 | 0.31215 | 266.11 | 142.89 |
| 12 | 0.26013 | 252.75 | 150.45 |
| 15 | 0.20810 | 240.02 | 158.42 |
| 18 | 0.17342 | 231.88 | 163.99 |
| 22 | 0.14189 | 224.70 | 169.23 |
| 26 | 0.12006 | 219.86 | 172.95 |
| 30 | 0.10405 | 216.37 | 175.74 |
| 35 | 0.08919 | 213.18 | 178.37 |
| 40 | 0.07804 | 210.82 | 180.36 |
| 50 | 0.06243 | 207.56 | 183.20 |
| 60 | 0.05203 | 205.41 | 185.12 |
| 80 | 0.03902 | 202.76 | 187.54 |
| 100 | 0.03122 | 201.18 | 189.01 |
| 120 | 0.02601 | 200.14 | 189.99 |
| 150 | 0.02081 | 199.10 | 190.98 |
| 200 | 0.01561 | 198.07 | 191.98 |

| | |
|---|---|
| CASE - II | |
| Gross head | 184 |
| Discharge | 1.2 |
| Mesilau | |

WATER HAMMER

1. PRESSURE WAVE VELOCITY

a = 1/(w/g*(1/K+D/E/t))^0.5

Where,

a : Pressure wave velocity (m/sec)
w : Unit weight of water (1.0 tonf/m3)
g : Accelation of gravity (9.8 m/sec2)
K : Bulk modulus of compressibility of water (2.07 x 10^5 tonf/m2)
E : Young's modulus of elasticity for pipe material (for steel pipe = 2.1 x 10^7 tonf/m2)

D : Diameter of pipe (m)
t : Pipe wall thickness (m)

| | D (m) | t (m) | a (m/sec) | Length (m) |
|---|---|---|---|---|
| Mesilau pipeline | 0.6 | 0.006 | 1010.7 | 990.0 |
| Penstock | 0.8 | 0.006 | 936.2 | 456.3 |
| - do - | 0.8 | 0.007 | 976.7 | 120.4 |
| - do - | 0.8 | 0.008 | 1010.7 | 90.3 |
| - do - | 0.8 | 0.009 | 1039.8 | 98.1 |
| - do - | 0.5 | 0.006 | 1055.3 | 15.0 |
| | | | | 1770.1 |

a = L/(L1/a1+L2/a2 ···· Ln/an)
= 989.978 m/sec

2. Water Hammer caused by the rapid closing of valve (in the case T < 2*L/a = 3.58 sec)

H-Ho = - a/g*(V-Vo)

Where, Ho : Water head in constant flowing situation (m)
Vo : Flow velocity in constant flowing situation (m)
H : Water head at a given time after the valve is operated (m)
V : Flow velocity at a given time after the valve is operated (m)

When valve is fully closed and V = 0, H-Ho =a*Vo/g is maximum additional head caused by water hammering.

In case of

Discharge in the pipeline : 1.20 m3/sec,
Mean velocity in the pipeline : 2.046 m/sec

Maximum additional head by water hammer is

H - Ho = 206.683 m

3. Simplified method of calculations for water hammer caused by slowly closing a valve
(in the case T > 2*L/a = 3.58 sec)

This formula is based on the assumption that from the time the first reflective returns to the valve until it is fully closed, the pressure remains unchanged and that the effective opening area of the valve is changed rectilinearly.

H/Ho = 1+n/2*(n+-(n^2+4)^0.5)

In this formula, + causes rise of the pressure at the time of closing the valve, whereas, - causes drop at the time of opening.

n = L*Vo/(T*g*Ho)

Where, T : Time of valve closing (sec)
L : Length of pipeline : 1770.1 (m)
Ho : 184 (m)
Vo : 2.047 (m/sec)

| Time (sec) | n | H (m) (closing) | H (m) (opening) |
|---|---|---|---|
| 10 | 0.20093 | 224.87 | 150.56 |
| 12 | 0.16744 | 217.50 | 155.66 |
| 15 | 0.13395 | 210.35 | 160.95 |
| 18 | 0.11163 | 205.72 | 164.58 |
| 22 | 0.09133 | 201.59 | 167.95 |
| 26 | 0.07728 | 198.78 | 170.32 |
| 30 | 0.06698 | 196.74 | 172.08 |
| 35 | 0.05741 | 194.87 | 173.74 |
| 40 | 0.05023 | 193.48 | 174.99 |
| 50 | 0.04019 | 191.54 | 176.75 |
| 60 | 0.03349 | 190.27 | 177.94 |
| 80 | 0.02512 | 188.68 | 179.44 |
| 100 | 0.02009 | 187.73 | 180.34 |
| 120 | 0.01674 | 187.11 | 180.94 |
| 150 | 0.01340 | 186.48 | 181.55 |
| 200 | 0.01005 | 185.86 | 182.16 |

## 6-4 Wall Thickness of Penstock

### WALL THICKNESS (from Liwagu Intake)

| No. | L (m) | TL (m) | EL (m) | H (m) | P (kg/cm2) | Ph (kg/cm2) | Pd (kg/cm2) | t (cm) | at (cm) | w (kg/m) | W (kg) | Wt (kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Liwagu headpond | 0 | 0 | 1043.0 | 5.0 | 0.5 | 0.0 | 0.5 | 0.0299 | 0.6 | 103.58 | 0 | 0 |
| | 2680.0 | 2680.0 | 1025.0 | 23.0 | 2.3 | 2.3 | 4.6 | 0.1510 | 0.6 | 103.58 | 277,594 | 277,594 |
| Penstock | 0 | 2680.0 | 1025.0 | 23.0 | 2.3 | 2.3 | 4.6 | 0.1704 | 0.6 | 118.38 | 0 | 0 |
| 1 | 15.0 | 2695.0 | 1024.0 | 24.0 | 2.4 | 2.3 | 4.7 | 0.1743 | 0.6 | 118.38 | 1,780 | 1,780 |
| 2 | 42.0 | 2737.0 | 1024.0 | 24.0 | 2.4 | 2.3 | 4.7 | 0.1755 | 0.6 | 118.38 | 4,972 | 6,752 |
| 3 | 34.0 | 2771.0 | 1016.0 | 32.0 | 3.2 | 2.3 | 5.5 | 0.2037 | 0.6 | 118.38 | 4,020 | 10,771 |
| 4 | 11.0 | 2782.0 | 1015.0 | 33.0 | 3.3 | 2.4 | 5.7 | 0.2074 | 0.6 | 118.38 | 1,308 | 12,079 |
| 5 | 19.0 | 2801.0 | 1015.0 | 33.0 | 3.3 | 2.4 | 5.7 | 0.2079 | 0.6 | 118.38 | 2,249 | 14,328 |
| 6 | 26.0 | 2827.0 | 1015.0 | 33.0 | 3.3 | 2.4 | 5.7 | 0.2087 | 0.6 | 118.38 | 3,078 | 17,406 |
| 7 | 64.3 | 2891.3 | 1009.0 | 39.0 | 3.9 | 2.4 | 6.3 | 0.2310 | 0.6 | 118.38 | 7,610 | 25,015 |
| 8 | 41.2 | 2932.5 | 989.0 | 59.0 | 5.9 | 2.5 | 8.4 | 0.3002 | 0.6 | 118.38 | 4,875 | 29,891 |
| 9 | 21.0 | 2953.5 | 980.0 | 68.0 | 6.8 | 2.5 | 9.3 | 0.3315 | 0.6 | 118.38 | 2,489 | 32,379 |
| 10 | 24.7 | 2978.2 | 971.0 | 77.0 | 7.7 | 2.5 | 10.2 | 0.3628 | 0.6 | 118.38 | 2,924 | 35,303 |
| 11 | 12.4 | 2990.6 | 968.0 | 80.0 | 8.0 | 2.5 | 10.5 | 0.3734 | 0.6 | 118.38 | 1,464 | 36,768 |
| 12 | 11.2 | 3001.8 | 963.0 | 85.0 | 8.5 | 2.5 | 11.0 | 0.3907 | 0.6 | 118.38 | 1,324 | 38,091 |
| 13 | 13.0 | 3014.8 | 963.0 | 85.0 | 8.5 | 2.5 | 11.0 | 0.3911 | 0.6 | 118.38 | 1,539 | 39,630 |
| 14 | 40.5 | 3055.3 | 952.0 | 96.0 | 9.6 | 2.6 | 12.2 | 0.4297 | 0.6 | 118.38 | 4,797 | 44,427 |
| 15 | 23.4 | 3078.7 | 944.0 | 104.0 | 10.4 | 2.6 | 13.0 | 0.4576 | 0.6 | 118.38 | 2,771 | 47,198 |
| 16 | 57.6 | 3136.3 | 927.0 | 121.0 | 12.1 | 2.7 | 14.8 | 0.5172 | 0.6 | 118.38 | 6,815 | 54,013 |
| | 0.0 | 3136.3 | 927.0 | 121.0 | 12.1 | 2.7 | 14.8 | 0.5172 | 0.7 | 138.10 | 0 | 54,013 |
| 17 | 42.4 | 3178.6 | 913.0 | 135.0 | 13.5 | 2.7 | 16.2 | 0.5661 | 0.7 | 138.10 | 5,853 | 59,866 |
| 18 | 20.4 | 3199.0 | 909.0 | 139.0 | 13.9 | 2.7 | 16.6 | 0.5803 | 0.7 | 138.10 | 2,817 | 62,682 |
| 19 | 30.7 | 3229.7 | 899.0 | 149.0 | 14.9 | 2.7 | 17.6 | 0.6152 | 0.7 | 138.10 | 4,236 | 66,919 |
| 20 | 26.9 | 3256.6 | 889.0 | 159.0 | 15.9 | 2.8 | 18.7 | 0.6500 | 0.7 | 138.10 | 3,718 | 70,637 |
| | 0.0 | 3256.6 | 889.0 | 159.0 | 15.9 | 2.8 | 18.7 | 0.6500 | 0.8 | 157.83 | 0 | 70,637 |
| 21 | 59.1 | 3315.7 | 861.0 | 187.0 | 18.7 | 2.8 | 21.5 | 0.7470 | 0.8 | 157.83 | 9,321 | 79,958 |
| 22 | 31.2 | 3346.9 | 857.4 | 190.6 | 19.1 | 2.8 | 21.9 | 0.7602 | 0.8 | 157.83 | 4,926 | 84,884 |
| | 0.0 | 3346.9 | 857.4 | 190.6 | 19.1 | 2.8 | 21.9 | 0.7602 | 0.9 | 177.56 | 0 | 84,884 |
| 23 | 4.0 | 3350.9 | 857.4 | 190.6 | 19.1 | 2.8 | 21.9 | 0.7603 | 0.9 | 177.56 | 714 | 85,598 |
| 24 | 32.1 | 3383.0 | 855.0 | 193.0 | 19.3 | 2.9 | 22.2 | 0.7694 | 0.9 | 177.56 | 5,693 | 91,291 |
| 25 | 33.0 | 3416.0 | 854.0 | 194.0 | 19.4 | 2.9 | 22.3 | 0.7737 | 0.9 | 177.56 | 5,862 | 97,153 |
| 26 | 16.0 | 3432.0 | 853.0 | 195.0 | 19.5 | 2.9 | 22.4 | 0.7776 | 0.9 | 177.56 | 2,847 | 99,999 |
| 27 | 13.0 | 3445.0 | 853.0 | 195.0 | 19.5 | 2.9 | 22.4 | 0.7780 | 0.9 | 177.56 | 2,308 | 102,308 |
| 28 | 0.0 | 3445.0 | 853.0 | 195.0 | 19.5 | 2.9 | 22.4 | 0.4919 | 0.6 | 73.98 | 0 | 102,308 |
| 29 | 15.0 | 3460.0 | 853.0 | 195.0 | 19.5 | 2.9 | 22.4 | 0.4921 | 0.6 | 73.98 | 2,219 | 104,527 |

Notes :
- TL : Length of pipeline
- EL : Elevation of center of pipe
- H : Static head
- P : Static pressure
- Ph : Water hammer pressure
- Pd : Design pressure
- t : Calculated thickness
- at : Adopted thickness
- W : Weight of pipe

## WEIGHT OF PIPELINES AND PENSTOCK

| Pipeline | t (mm) | Length (m) | Weight (ton) |
|---|---|---|---|
| Liwagu Pipeline D = 700 | 6 | 2680.0 | 277.6 |
| Mesilau Pipeline | 6 | 990.0 | 87.9 |
| Connecting pipe D = 600 | 6 | 90.0 | 8.0 |
| Penstock | | | |
| D = 800 | 6 | 456.3 | 54.0 |
| | 7 | 120.4 | 16.6 |
| | 8 | 90.3 | 14.2 |
| | 9 | 98.1 | 17.4 |
| D = 500 | 6 | 30.0 | 2.2 |
| | Penstock | 795.0 | 104.5 |

# Appendix 7 CONSTRUCTION COSTS

Appendix 7

# CONSTRUCTION COSTS

## CONTENTS

**Summary of Construction Cost**

| Description | Amount (M$) |
|---|---|
| 1. Civil Engineering Works | 6,099,000 |
| 1.1 Preliminaries | 200,000 |
| 1.2 Liwagu Intake Facilities | 509,000 |
| 1.3 Mesilau Intake Facilities | 647,000 |
| 1.4 Liwagu Pipeline | 2,284,000 |
| 1.5 Mesilau Pipeline | 543,000 |
| 1.6 Penstock | 813,000 |
| 1.7 Powerhouse | 175,000 |
| 1.8 Access Road | 928,000 |
| 2. Electrical and Mechanical Works | 3,150,000 |
| 3. Transmission Line | 140,000 |
| 4. Project Land Cost and Compensations | 250,000 |
| 5. Engineering and Management (10% of above total) | 965,000 |
| 6. Contingencies | 896,000 |
| 10% of Civil Engineerings Works | 610,000 |
| 5% of Electrical and Mechanical Works | 158,000 |
| 5% of Transmission Lines | 7,000 |
| 10% of Project Land Cost and Compensations | 25,000 |
| 10% of Engineering, Management and Commissioning | 96,000 |
| Grand Total | 11,500,000 |

Construction Cost No. 1

1.2 Liwagu Intake Facilities

1.2.1 Intake Dam and Desilting Basin

| Description | Unit | Q'ty | Unit Price (M$) | Amount (M$) |
|---|---|---|---|---|
| Site clearance & Setting out | L.S | 1 | 7,000 | 7,000 |
| Temporary river diversion works | L.S | 1 | 75,000 | 75,000 |
| Excavation in soft material | m^3 | 100 | 7 | 700 |
| Excavation in river gravel | m^3 | 800 | 10 | 8,000 |
| Excavation in rock | m^3 | 40 | 60 | 2,400 |
| Mass concrete (1;3;6) | m^3 | 410 | 220 | 90,200 |
| Structurel concrete (1;2;4) | m^3 | 240 | 300 | 72,000 |
| Reinforcement | t | 14 | 1,850 | 25,900 |
| Embankment | m^3 | 70 | 10 | 700 |
| Gabion (1.5×1.0×0.5m) | Set | 60 | 80 | 4,800 |
| Scouring gate (0.7×0.9m) | Set | 2 | 8,000 | 16,000 |
| Miscellaneous (5%) | L.S. | 1 | | 15,300 |
| Total | | | | 318,000 |

1.2.2 Headpond

| Description | Unit | Q'ty | Unit Price (M$) | Amount (M$) |
|---|---|---|---|---|
| Site clearance & Setting out | L.S | 1 | 5,000 | 5,000 |
| Excavation in soft material | m^3 | 100 | 7 | 700 |
| Excavation in river gravel | m^3 | 250 | 10 | 2,500 |
| Excavation in rock | m^3 | 50 | 60 | 3,000 |
| Embankment | m^3 | 960 | 10 | 9,600 |
| Facing concrete (1;2;4) | m^3 | 180 | 300 | 54,000 |
| Structure concrete (1;2;4) | m^3 | 200 | 300 | 60,000 |
| Reinforcement | t | 12 | 1,850 | 22,200 |
| PVC Waterstop | m | 200 | 20 | 4,000 |
| Gravel | m^3 | 135 | 46 | 6,210 |
| Scouring gate (0.7×0.9m) | Set | 1 | 8,000 | 8,000 |
| Stop gate (0.7×0.7m) | Set | 1 | 7,000 | 7,000 |
| Miscellaneous (5%) | L.S | | | 8,790 |
| Total | | | | 191,000 |

Construction Cost No. 3

## 1.3 Mesilau Intake Facilities

### 1.3.1 Intake Dam and Desilting Basin

| Description | Unit | Q'ty | Unit Price (M$) | Amount (M$) |
|---|---|---|---|---|
| Site clearance & Setting out | L.S | 1 | 7,000 | 7,000 |
| Temporary river diversion work | L.S | 1 | 75,000 | 75,000 |
| Excavation in soft material | m^3 | 180 | 7 | 1,260 |
| Excavation in river gravel | m^3 | 180 | 10 | 1,800 |
| Excavation in rock | m^3 | 90 | 60 | 5,400 |
| Embankment | m^3 | 600 | 10 | 6,000 |
| Mass concrete (1;3;6) | m^3 | 440 | 220 | 96,800 |
| Structure concrete (1;2;4) | m^3 | 300 | 300 | 90,000 |
| Reinforcement | t | 11 | 1,850 | 20,350 |
| Gabion (1.5×1.0×0.5m) | Set | 60 | 80 | 4,800 |
| Scouring gate (0.6×0.7m) | Set | 1 | 6,000 | 6,000 |
| Scouring gate (1.4×1.2m) | Set | 1 | 12,000 | 12,000 |
| Stop gate (0.9×0.9m) | Set | 1 | 10,000 | 10,000 |
| Miscellaneous (5%) | L.S | 1 | | 16,590 |
| Total | | | | 353,000 |

1.3.2 Headpond

| Description | Unit | Q'ty | Unit Price (M$) | Amount (M$) |
|---|---|---|---|---|
| Site clearance & Setting out | L.S | 1 | 5,000 | 5,000 |
| Excavation in soft material | m^3 | 3,000 | 7 | 21,000 |
| Excavation in rock | m^3 | 500 | 60 | 30,000 |
| Embankment | m^3 | 1,200 | 10 | 12,000 |
| Facing concrete (1;2;4) | m^3 | 200 | 300 | 60,000 |
| Structure concrete (1;2;4) | m^3 | 100 | 300 | 30,000 |
| Reinforcement | t | 7 | 1,850 | 12,950 |
| PVC Waterstop | m | 250 | 20 | 5,000 |
| Gravel | m^3 | 150 | 46 | 6,900 |
| Masonry | m^3 | 25 | 50 | 1,250 |
| Supply & inst. of connecting pipe (D=600mm) | m | 90 | 450 | 40,500 |
| Supply & inst. of scouring pipe (D=700mm) | m | 36 | 700 | 25,200 |
| Scouring valve (D=700mm) | Set | 1 | 30,000 | 30,000 |
| Stop valve (D=600mm) | Set | 1 | 22,000 | 22,000 |
| Miscellaneous (5%) | L.S | 1 | | 14,200 |
| Total | | | | 294,000 |

## Construction Cost No. 5

1.4 Liwagu Pipeline

| Description | Unit | Q'ty | Unit Price (M$) | Amount (M$) |
|---|---|---|---|---|
| Site clearance & Setting out | L.S | 1 | 38,000 | 38,000 |
| Excavation in soft material | m^3 | 940 | 7 | 6,580 |
| Excavation in rock | m^3 | 0 | 60 | 0 |
| Supply & inst. of steel pipe (D=700mm, t=6mm) | m | 2,680 | 700 | 1,876,000 |
| Saddle concrete (1;2;4) | m^3 | 300 | 300 | 90,000 |
| Anchor block & pier concrete (1;2;4) | m^3 | 130 | 220 | 28,600 |
| Reinforcement | t | 14 | 1,850 | 25,900 |
| Steel bridge for pipeline :l=30m | Set | 1 | 35,000 | 35,000 |
| Steel bridge for pipeline :l=20m | Set | 2 | 20,000 | 40,000 |
| Gravell | m^3 | 120 | 46 | 5,520 |
| Stope valve (D=700mm) | Set | 1 | 30,000 | 30,000 |
| Miscellaneous (5%) | L.S | 1 | | 108,400 |
| Total | | | | 2,284,000 |

## Construction Cost No. 6

1.5 Mesilau Pipeline

| Description | Unit | Q'ty | Unit Price (M$) | Amount (M$) |
|---|---|---|---|---|
| Site clearance & Setting out | L.S | 1 | 20,000 | 20,000 |
| Excavation in soft material | m^3 | 160 | 7 | 1,120 |
| Excavation in rock | m^3 | 0 | 60 | 0 |
| Supply & inst. of steel pipe (D=600mm, t=6mm) | m | 990 | 450 | 445,500 |
| Saddle concrete (1;2;4) | m^3 | 60 | 300 | 18,000 |
| Anchor block concrete (1;2;4) | m^3 | 20 | 220 | 4,400 |
| Reinforcement | t | 3 | 1,850 | 5,550 |
| Gravell | m^3 | 9 | 46 | 414 |
| Stop valve (D=600mm) | Set | 1 | 22,000 | 22,000 |
| Miscellaneous (5%) | L.S | 1 | | 26,016 |
| Total | | | | 543,000 |

## Construction Cost No. 7

### 1.6 Penstock

| Description | Unit | Q'ty | Unit Price (M$) | Amount (M$) |
|---|---|---|---|---|
| Site clearance & Setting out | L.S. | 1 | 44,000 | 44,000 |
| Excavation in soft material | m^3 | 2,900 | 7 | 20,300 |
| Rock excavation | m^3 | 720 | 60 | 43,200 |
| Sand foundation for penstock | m^3 | 620 | 40 | 24,800 |
| Backfill for penstock | m^3 | 1,600 | 10 | 16,000 |
| Supply & inst. of steel pipe (D=700&600mm, t=6mm) | m | 473 | 1,150 | 543,950 |
| Supply & inst. of steel pipe (D=700&600mm, t=7mm) | m | 120 | 1,270 | 152,400 |
| Supply & inst. of steel pipe (D=700&600mm, t=8mm) | m | 90 | 1,350 | 121,500 |
| Supply & inst. of steel pipe (D=700&600mm, t=9mm) | m | 85 | 1,400 | 119,000 |
| Supply & inst. of steel pipe (D=500mm, t=6mm) | m | 32 | 380 | 12,160 |
| Anchor block concrete (1;2;4) | m^3 | 140 | 220 | 30,800 |
| Reinforcement | ton | 3 | 1,850 | 5,550 |
| Slope protection (Seeding) | m^2 | 3,200 | 2 | 6,400 |
| Concrete pile (D=300mm, l=1.5m) | p.c | 50 | 45 | 2,250 |
| Miscellaneous (5%) | L.S | 1 | | 54,940 |
| Total | | | | 1,151,000 |

Construction Cost No.8

1.7 Powerhouse

| Description | Unit | Q'ty | Unit Price (M$) | Amount (M$) |
|---|---|---|---|---|
| Site clearance & Setting out | L.S | 1 | 7,000 | 7,000 |
| Excavation in soft material | m^3 | 2,700 | 7 | 18,900 |
| Excavation in rock | m^3 | 300 | 60 | 18,000 |
| Embankment | m^3 | 0 | 5 | 0 |
| Base concrete (1;2;4) | m^3 | 0 | 220 | 0 |
| Structure concrete (1;2;4) | m^3 | 130 | 300 | 39,000 |
| Reinforcement | t | 4 | 1,850 | 7,400 |
| Slope protection (Seeding) | m^2 | 340 | 2 | 680 |
| Gravel | m^3 | 170 | 46 | 7,820 |
| Precast concrete gutter (30×30m) | m | 50 | 22 | 1,100 |
| Superstructure | L.S | 1 | 50,000 | 50,000 |
| Hoist with girder | L.S | 1 | 16,800 | 16,800 |
| Miscellaneous (5%) | L.S. | 1 | | 8,300 |
| Total | | | | 175,000 |

## Construction Cost No.9

1.8 Access Road

| Description | Unit | Q'ty | Unit Price (M$) | Amount (M$) |
|---|---|---|---|---|
| Type A | m | 2,980 | 206 | 613,880 |
| Type B | m | 2,480 | 109 | 270,320 |
| Miscellaneous | L.S. | 1 | | 43,800 |
| Total | | | | 928,000 |

| | | | | | |
|---|---|---|---|---|---|
| Type A | Site clearance | m | 1 | 5 | 5 |
| | Slope protection (Seeding) | m | 6 | 2 | 12 |
| | Excavation | m^3 | 18 | 4 | 70 |
| | Gravel | m^3 | 1 | 46 | 28 |
| | Precast concrete gutter (30×30cm) | m | 1 | 22 | 22 |
| | Concrete wall | m^3 | 0 | 300 | 60 |
| | Hume concrete pipe | m | 0 | 230 | 9 |
| | Total | | | | 206 |
| Type B | Site clearance | m | 1 | 5 | 5 |
| | Slope protection (Seeding) | m | 2 | 2 | 4 |
| | Excavation | m^3 | 9 | 4 | 35 |
| | Gravel | m^3 | 1 | 46 | 28 |
| | Concrete wall | m^3 | 0 | 300 | 30 |
| | Hume concrete pipe | m | 0 | 230 | 7 |
| | Total | | | | 109 |

## Construction Cost No.10

2. Electrical and Mechanical Works

| Description | Unit | Q'ty | Unit Price | Amount |
|---|---|---|---|---|
| Turbine and Generator | L.S. | 1 | | 2,012,000 |
| Transformer | L.S. | 1 | | 214,000 |
| Telecommunication | L.S. | 1 | | 198,000 |
| Transportation | L.S. | 1 | | 242,000 |
| Installation (including miscellaneous materials) | L.S. | 1 | | 484,000 |
| Total | | | | 3,150,000 |

# Appendix 8 ENVIRONMENTAL IMPACT STUDY

Appendix 8

# ENVIRONMENTAL IMPACT STUDY

## CONTENTS

**Lembaga Letrik Sabah**
**Kota Kinabalu**

# SMALL SCALE HYDROELECTRIC POWER DEVELOPMENT PROJECT AT UPPER LIWAGU RIVER BASIN IN SABAH

## *ENVIRONMENTAL IMPACT ASSESSMENT*

**Final Report**

**May 1992**

**Biro Penyelidikan dan Perundingan**
**Universiti Kebangsaan Malaysia**

# EXECUTIVE SUMMARY

## BACKGROUND

Sabah Electricity Board (SEB) proposes to install a small hydroelectric power generation facilities in the vicinity of Kg. Naradaw, Kundasang, Sabah to cater for the growing power demand of the population and development activities along the Kundasang - Ranau grid.

The proposed Naradaw scheme is a run of river type, comprising two intake weirs: one will be on Sg. Liwagu proper and the second on Sg. Mesilau. Water extracted from these two intake weirs will be piped to a head pond before being surged down to a power house located near the confluence of the two rivers. The Naradaw site has a total catchment area of 59.2 $km^2$, enabling a design maximum discharge of 1.18 $m^3/s$. With a net head of 169 m, the installed capacity of the hydroplant is estimated at 1.6 MW.

The aim of the present study is to investigate and describe the existing status of the physicochemical, biological and human components of the environment within and in the vicinity of the project area, and thereon predict the potential impacts of the activities related to the proposed hydroelectric installation as well as suggesting appropriate mitigation and abatement measures for incorporation into the project plan.

## EXISTING ENVIRONMENT

**CLIMATE:** The areas along the upper reaches of the Liwagu River are influenced by the southwest monsoon with rainy seasons between May - October, and dry seasons between February - April. Kundasang has one of the lowest recorded average annual rainfalls in Sabah i.e. 2,313 mm presumably due to the rainshadow effect. On the average about 1001 mm per year of rainfalll is available for runoff and infiltration into the ground. There is little seasonal variation of temperature in Kundasang; the hottest month, May, has a monthly mean daily maximum of 25.7°, the coolest being January, at 22.5°.

**TOPOGRAPHY:** Slopes in the Study Area are generally steep. The Naradaw site has a mountainland of elevations from 840 to 1,040 m, through which the Liwagu River and the Mesilau River meander from west-northwest to east-southeast. The gradient of the Liwagu river is approximately 1/19, while that of the Mesilau River is approximately 1/15. Slopes generally inclined 20 to 45 degrees, and parts of the slopes show old or new signs of landslides.

**GEOLOGY:** The project area is underlain by sedimentary rocks of Crocker Formation consisting of sandstone with minor shale/mudstone and siltstone alternations. Unconformably overlying the Crocker is the Pinosuk Gravel and recent riverine alluvium. The Crocker Formation has been extensively faulted with no prefered orientation of fault lines.

Weathered to freshly fractured sandstone boulders of the Crocker Formation are found at the intake site of the Liwagu River. At the Mesilau intake, strongly brecciated sandstone of the Crocker Formation were found at the depth of about 6 metres below the river bed.

The main soil associations found in the Study Area are those of Pinosuk, Trusmadi and Crocker Associations. The soil is suitable for the cultivation of vegetables, but because of the steepness of the terrain, there is a strong erosion risk.

From seismological data, recorded earthquakes west of Ranau have had magnitude ranging from 4 - 5.9 on the Richter scale, and are of shallow depth (less than 70 km). The most recent earthquake in this part of Sabah measuring 5 on the Ritcher Scale accurred on 27 May 1991, followed by series of aftershocks during the following weeks.

**DRAINAGE:** The project area lies within the catchment area of the Sg. Liwagu, which flows generally eastwards, eventually emerging in Labuk Bay on the Sulu Sea. Its source is in the Kinabalu Park, and it is this river which provides water for consumption in the Ranau District. The main tributaries upstream of the project area is Sg. Mesilau East and West and Sg. Silau Silau. The catchment areas for the Mesilau rivers upstream of the proposed intake point is estimated to be about 28 km$^2$ and that for Sg. Liwagu proper is 31 km$^2$.

**LAND USE:** Agricultural sector represents the main production base for the economy of the project area. The swidden agriculture appears to have given way to a more settled farming method. Their effort is being facilitated by Government agencies such as the Koperasi Pembangunan Desa (KPD) which provides water supply and sprinkler system. Most holdings appear to range from 0.6 - 0.8 ha. in size. The total area of cultivated land in Kundasang in 1984 was estimated about 750 ha. The crops most commonly grown on the holdings are mixed, non-tree crop horticulture some of which are indigenous to temperate climates. In addition to growing vegetables, many local residents keep some form of livestock.

**WATER USE:** The water use in the upstream area of the project site are in three main areas viz. Bundu Tuhan, Kundasang, and Pinosuk Plateau. The estimated water demand for various uses (domestic, agriculture, commercial

›ther municipal uses) in the three areas for 1990 is estimated at nearly 22 ) (equivalent to 1.16 cumecs).

**WATER QUALITY:** Field observation indicates that the Liwagu Mesilau rivers are being directly affected by the agricultural, urbanisation, ;m and recreational activities in the Upper Liwagu basin although the DOE ds show that the water quality at Ranau still belongs to Class I water. Water ;y exaimination within the project area shows relatively high loading of dis- ;l solids, organics and phosphates although the dissolved oxygen level in cases are near saturation point. Available data indicate that none of the ıon organochlorine pesticides occur at detectable concentration in water al- ;h low quantities of these pesticides have been detected in sediment samples.

**VEGETATION:** The vegetation of this area is essentially that ver montane rain forest which is characterised by two floristic zones, namely ıpper dipterocarp forest (roughly at 750 - 900 m altitude) and oak-laurel : (900 - 1800 m). Although the original hillslope vegetation has mostly been ;d and replaced with commercial vegetable plot, there are still a few remnant ıry species along the Liwagu and Mesilau river valleys; these include *rocarpus* sp., *Aglaia* sp., *Shorea* sp., *Eleocarpus* sp. and *Diospyros* sp. Areas have been severely affected by shifting cultivation (slash and burnt) are ver dominated by the secondary species which include *Melochia umbellata, auclea gigantea, Brookea dasyntha, Trema* sp. and others. The above ground ass at the proposed powerhouse site was found to be only about 16 tonne/ No unique floral species of special conservation or scientific interests have found here.

**WILDLIFE:** Fauna representing the original community was l within the remnants of the riverine reserves. The presence of *Amolops headi* and *Ansonia longidigita* in the Mesilau river implies the existence originally larger amphibian community typical of hill forest. Nevertheless, substantial ıer of *Bufo juxtasper* in the Mesilau river indicates a trend towards the ification of the amphibian community caused by deforestation. Modification e Mesilau-Liwagu valleys is also evidenced by the high relative abundance of in colonising bird species (bulbuls, prinias, munias) typical of the distrubed ats of the lowlands. Few mammals were caught or sighted, again species ıl of disturbed lowland/hill forest. No rare or endangered species were re- ;d.

**AQUATIC LIFE:** Of the 11 species of fish caught at the pro- l Mesilau intake point, eight belongs to Gastromyzontidae. At the Liwagu e, 15 species of fish have been sampled, 12 were found to belong to the y Gastromyzontidae, two species from Anguillidae and only one species from nidae. Of the 12 species caught from the Liwagu-Mesilau confluence, 10 from the family Gastromyzontidae and 2 species from the family Anguilli- Thus, at the range of altitude where the hydro scheme is to be located, the dominant fish family found in the streams were Gastromyzontidae.

**HUMAN ENVIRONMENT:** The proposed project will acquire about 10 ha. of land for laying the pipe, power house and the pond. Most of these lands are private lands. About five houses have to be relocated as they are located very close to the pipeline and the power house. All households in the study area belong to the lower income group of less than $400 per month.

The survey reveals that about 76 percent of respondents agreed the project to be built in the proposed site, 16 percent disagreed and the rest had no opinion. Those who disagreed feel that the area is not suitable for the hydro-electric project in view of constant water shortages.

## POTENTIAL IMPACTS

**INVESTIGATION STAGE:** The potential impacts of the site surveying, engineering and geophysical investigations are expected to be of low magnitude. Nevertheless, the entry of the investigation team should be made known to the kampung head.

**CONSTRUCTION AND DEVELOPMENT STAGE:** Earth work and excessive use of the existing Kauluan gravel road can cause among others, (i) damage to the road, (ii) soil erosion and slope failure, (iii) increase in suspended sediment in stream waters, (iv) increase of airborne particulates during dry periods, (v) noise from the machineries deployed, and (vi) inherent risks to human safety both of onsite workers and the surrounding neighbourhood. The construction of intake weirs can result in immediate siltation of downstream water if the flow is not properly diverted. Indiscriminate disposal of wastes into the surrounding water bodies can seriously affect the aquatic ecosystem and downstream water use. Appropriate mitigation measures must therefore be taken during the civil works.

**OPERATION AND MAINTENANCE:** Major environmental issues that can be associated with the operation and maintenance of the proposed small scale upper Liwagu HEP project are (i) the power generation activities, particularly with regard to water extraction, and (ii) waste disposal.

Water quantity for the Liwagu and Mesilau rivers upstream of the intake points, and also the Liwagu river downstream of the power house will not be affected, as what comes into the HEP plant system will go out.

However, for the stretch between the intake points and the power house, there will be some reduction in flow. The reduction in river water quantity between the intake points and the powerhouse may lead to a number of adverse implications, the most critical being possible loss of habitat for aquatic life. Another potential negative impact will be creation of sites for mosquito breeding as low flows will lead to formation of small water pools in the rocky bed.

The ponding of water is not expected to affect the downstream water quality as the retention time in the pond is only about 2 hours.

Solid wastes, particularly the silt/sludge from the headpond and used lubrication oil from the power plant maintenance must be properly managed to avoid pollution of downstream water.

**RECOMMENDATIONS**

Based on the information gathered of the existing environment and the proposed development and operational plans, major recommendations with regard to environmental preservations are as follows:

1) In view of the pressing demand for water resource by the various users within the upper Liwagu catchment area, an accurate water auditing must be worked out to verify the feasibility of the proposed HEP project and avoid adverse environmental implications associated with water quantity.

2) During low flows, priority must be given to allocating sufficient quantity of flow for river maintenance purposes (for the intake - powerhouse stretch); the minimum flow recommended is 0.05 cumecs for Sg. Mesilau and 0.10 cumecs for Sg. Liwagu.

3) Affected villagers must be appropriately compensated for losses due to displacement or acquisition of land, prior to commencement of construction work.

4) As the area is still tectonically active, structures must be firmly anchored to the bedrocks; all installations must incorporate adequate safety features to minimise impact in case of foundation failure.

5) All engineering works must incorporate strict erosion control measures to minimise siltation problem of surface waters during the construction stage.

Table 1.0 summarises the potential impacts and recommended mitigation and abatement measures for the proposed upper Liwagu HEP project.

TABLE 1.0. SUMMARY OF POTENTIAL IMPACTS AND MITIGATING MEASURES OF THE PROPOSED UPPER LIWAGU SMALL-SCALE HYDROPOWER PROJECT

| ITEM | PROJECT ACTIVITIES AND SOURCES OF POLLUTANTS | POTENTIAL IMPACTS | NATURE S (short-term) L (long-term) P (permanent) | PROPOSED MITIGATION MEASURES | RESIDUAL IMPACTS |
|---|---|---|---|---|---|
| **A. INVESTIGATION STAGE** | | | | | |
| Site surveying and engineering/geotechnical investigation. | | Minimal in terms of traffic related impacts (airborne dust,road safety, noise) | S | | |
| | | May cause anxiety among population. | S | First inform the village head. | |
| | | Minimal impacts on biological components. | | Ensure minimal cutting of rentices/ riparian vegetation. | |
| *Note: No new access road required.* | | | | | |
| **B. CONSTRUCTION AND DEVELOPMENT** | | | | | |
| 1. | **Access road** | Reduction in surface water quality. | S | Make use of existing roads rather than cutting new roads. | |
| | *Note: Existing roads are unsurfaced and on hillslopes.* | | S | Road surface to be improved (gravelled and compacted to appropriate specification). | |
| | | | | Proper drainage should be provided for newly built stretch. | |
| | | Reduction in air quality. | S | Water to be lightly sprayed on access roads when dust is excessive. | |
| | | Increase in noise. | S | Working hours limited to daytime only. | |
| | | Degradation of roads due to overloading. | S | Close supervision by Site Engineer | |
| | | | | Roads to be immediately resurfaced if damaged during usage. | |
| | | Some loss in agriculture land | P | Affected land owners to be compensated for new road stretch that cut across vegetable farms. | |

TABLE 1.0. SUMMARY OF POTENTIAL IMPACTS AND MITIGATING MEASURES OF THE PROPOSED UPPER LIWAGU SMALL-SCALE HYDROPOWER PROJECT - cont'd

| ITEM | PROJECT ACTIVITIES AND SOURCES OF POLLUTANTS | POTENTIAL IMPACTS | NATURE S (short-term) L (long-term) P (permanent) | PROPOSED MITIGATION MEASURES | RESIDUAL IMPACTS |
|---|---|---|---|---|---|
| 2 | **Site clearing** | Increased suspended solids in surface water due to surface erosion. | S | Attempt should be made at synchronising site clearing with dry periods. | |
| | *Note:* o *The area is generally devoid of primary vegetation (replaced with vegetable farms).* o *There are no endangered and rare plant and wildlife species in the area.* | | | Minimal cutting of riparian vegetation; replanting cleared strips. | |
| | | | | Provision of temporary drain and silt trap around headpond and powerhouse areas. | |
| | | | | Exposed steep slopes to be protected with plastic sheeting. | |
| | | | | Use excess earth for road grading and bunds. | |
| | | Increase in noise level. | S | Working hours near settlement areas to be limited to daytime. | |
| | | Increase in suspended particulates in the air. | S | Water to be sprinkled during dry periods. | |
| | | | | Plant debris must not be burnt on-site but properly stacked along the riparian or hill slopes to act as silt screen. | |
| | | Displacement of houses *(Note: Land acquisition not extensive)* | P | Affected population should be adequately compensated. | Displacement of about five households. |
| | | | | Resettlement of affected household to be completed first prior to site clearing. | |
| 3 | **Earthworks** | Increase in suspended particulates in air prior to stabilisation. | S | Spray water when dust is excessive. | |
| | | Increase in suspended solids due to erosion by runoff. | S | Construct temporary drains which lead to a silt trap or settling pond. | |

TABLE 1.0. SUMMARY OF POTENTIAL IMPACTS AND MITIGATING MEASURES OF THE PROPOSED UPPER LWAGU SMALL-SCALE HYDROPOWER PROJECT - cont'd

| ITEM | PROJECT ACTIVITIES AND SOURCES OF POLLUTANTS | POTENTIAL IMPACTS | NATURE S (short-term) L (long-term) P (permanent) | PROPOSED MITIGATION MEASURES | RESIDUAL IMPACTS |
|---|---|---|---|---|---|
| | | | | Earthwork is best confined to periods of expected low precipitation. | |
| | | | | Excess earth to be stockpiled on levelled ground and compacted, or used for road grading or bunding. | |
| | | | | Earthwork should be phased so as not to allow too much area being exposed to erosion at any one time. Exposed areas to be revegetated/turfed immediately upon completion of earthwork. | |
| | | Siltation of streams during construction of intake weirs. | S | Proper diversion of stream flow. | |
| | | Slope failure. | S | Minimal cutting of slope.<br>Slope to be cut or cleared of vege-tation only when the site is ready to be worked on. Work first from higher ground. | |
| | | Increase in noise due to earthwork machinery. | S | Working time near settlement areas to be limited to day time only. | |
| | | Reduction of aesthetics. | | Good landscaping work, particularly around headpond and powerhouse. | |
| 4 | **Transportation** | Increase in suspended particulates in air. | S | Lorry loads must be covered to avoid spillage. | |
| | | | | Sprinkling of road and tracks when dust is excessive. | |
| | | Decrease in tranquility. | S | Transportation movement to be restricted to daytime. | |

TABLE 1.0. SUMMARY OF POTENTIAL IMPACTS AND MITIGATING MEASURES OF THE PROPOSED UPPER LIWAGU SMALL-SCALE HYDROPOWER PROJECT - cont'd

| ITEM | PROJECT ACTIVITIES AND SOURCES OF POLLUTANTS | POTENTIAL IMPACTS | NATURE S (short-term) L (long-term) P (permanent) | PROPOSED MITIGATION MEASURES | RESIDUAL IMPACTS |
|---|---|---|---|---|---|
| | | Safety hazards. | S | Safety regulation and normal construction supervision to be enforced. | |
| | | | | Minimise number of trips by proper planning. | |
| 5 | **Material and equipment** | Increase in noise. | S | Working hours in Kg. Naradaw is limited to daytime only. | |
| | | Safety hazard in storage area | S | Machines, pipes etc. to be stored away from the public right of way and guarded. | |
| | | Risk of accident at construction site. | S | Safety regulation and normal construction supervision to be enforced. | |
| 6 | **Waste disposal** | Deterioration of water quality. | S | Proper management of wastes (e.g. use of covered containers/pit) | |
| | | | | Excess earth to be reused or properly stocked. Other construction wastes to be disposed off at approved waste dump site. | |
| | | | | No open burning on-site. | |
| | | | | No full scale maintenance work on machineries/ vehicles be allowed in the project area. | |
| | | Water contamination by sewage. | S | Provision of temporary septic tank to worker quarters. | |
| 7 | **Base camp** | Indiscriminate dumping of wastes lead to ground and water pollutions - potential health hazard. | S | Proper management of wastes (see Waste Disposal). | |
| 8 | **Labour force** | Employment opportunities (+ve impact) | S | (Job priority given to locals). | |

TABLE 1.0. SUMMARY OF POTENTIAL IMPACTS AND MITIGATING MEASURES OF THE PROPOSED UPPER LIWAGU SMALL-SCALE HYDROPOWER PROJECT - cont'd

| ITEM | PROJECT ACTIVITIES AND SOURCES OF POLLUTANTS | POTENTIAL IMPACTS | NATURE S (short-term) L (long-term) P (permanent) | PROPOSED MITIGATION MEASURES | RESIDUAL IMPACTS |
|---|---|---|---|---|---|
| 9 | **Scenic modification** | Loss of natural scenery particularly at headpond - pumphouse area. | P | Replace with good landscape, and revegetated. | Man-made structure. |
| | | Obstruction to human and animal passage | P | Minimise by bunding the blocking segment. Good landscaping. | |
| 10 | **Abandonment** | Safety: abandoned structures and machineries could be hazardous. | S | Dangerous machineries to be stored/parked in a guarded premise. | |
| C. | **OPERATION AND MAINTENANCE STAGE** | | | | |
| 11 | **Power generation** | Reduced flow between intake and powerhouse **during low flows:** | P | | |
| | | a. impacting aquatic life (loss of habitat) | | Ensure a minimum of 0.05 and 0.10 cumecs of flow for Mesilau and Liwagu, respectively, for river maintenance (minimum 6" depth). | |
| | | b. affecting direct water use | | Possibly compensate by distributing a fraction of ponded water to nearby population. | |
| | | c. possible mosquito breeding | | Alternate day flushing during dry periods. | |
| | | d. temporal reduction in water quantity for downstream users due to flow regulation. | | Headpond storage must not exceed 2000 $m^3$. | |
| | | Noise | P | Proper installation of pipeline and genset to minimise vibration. | |
| | | Risk of headpond and pipeline collapse/ rupture | | Installation of fail-safe system (including control valves and bundwalls at strategic points; consider alarm system. Structures (including pipeline support) must be anchored firmly on bedrocks. | |

TABLE 1.0. SUMMARY OF POTENTIAL IMPACTS AND MITIGATING MEASURES OF THE PROPOSED UPPER LIWAGU SMALL-SCALE HYDROPOWER PROJECT - cont'd

| ITEM | PROJECT ACTIVITIES AND SOURCES OF POLLUTANTS | POTENTIAL IMPACTS | NATURE S (short-term) L (long-term) P (permanent) | PROPOSED MITIGATION MEASURES | RESIDUAL IMPACTS |
|---|---|---|---|---|---|
| | | Deterioration of water quality on impact | | Installation of impact buffering structure (impact of this slight turbulence is counterbalanced by the SS removal in the headpond). | |
| 12 | **Infrastructure and Utility** | | | | |
| | a) Road | Anticipated improved road pavement upon completion of project (a positive impact) | L | | |
| | b) Water Supply | | | See item 11(b). | |
| | c) Power Supply | Improved power supply along the Kundasang - Ranau grid ( a positive impact) | L | | |
| 13 | **Waste disposal** | Headpond sludge - potential contamination of river water by nutrients and pesticides. | L | Silt/sludge to be stockpiled on the levelled ground adjacent to the headpond. Encourage reuse for agricultural soil conditioning. | |
| | | Oil wastes from genset maintenance - water contamination. | L | Collected (oil sump, drums), carefully stored and returned to supplier. | |

# Appendix 9 TECHNICAL SPECIFICATIONS

Appendix 9

# TECHNICAL SPECIFICATIONS FOR FIELD INVESTIGATIONS

## CONTENTS

MALAYSIA

# FEASIBILITY STUDY
ON
# SMALL SCALE HYDROELECTRIC POWER DEVELOPMENT PROJECT AT UPPER LIWAGU RIVER BASIN IN SABAH

# TECHNICAL SPECIFICATIONS
FOR
# FIELD INVESTIGATIONS

SEPTEMBER, 1991

JAPAN INTERNATIONAL COOPERATION AGENCY

# CONTENTS

# I. TOPOGRAPHIC SURVEY

## 1. General

The Specification shall be applicable to the topographic survey to be performed in order to obtain data necessary for the preliminary design of the Feasibility Study of the Small Scale Hydroelectric Power Development Project at Upper Liwagu River Basin in Sabah, Malaysia.

## 2. Scope of Work

The detailed work plan and quantities shall be fixed later. However, the work quantities are as follows:

| | | |
|---|---|---|
| 1/500 scale topographic survey are | : | 0.098 $Km^2$ |
| - Intake dam at Liwagu river | : | 0.012 $Km^2$ |
| - Intake dam at Mesilau river | : | 0.017 $Km^2$ |
| - Penstock and powerhouse | : | 0.069 $Km^2$ |

The location of the Work is shown in Fig. I.1 and has been prepared based on the existing topographic map at a scale of 1/5,000.

## 3. Work Plan

The work plans are attached in Fig. I.2 - I.4, and has been prepared based on the existing topographic map at a scale of 1/2,500.

## 4. Work Period

The topographic survey shall be completed by 31 January 1992.

## 5. Technical Specifications

All measurement shall be expressed in the metric system and the language shall be English.

## 5.1 1/500 Scale Topographic Survey

The topographic maps at a scale of 1/500 shall be prepared for proposed areas and their surroundings, which include the planned intake dam, headrace route, head tank, penstock route, power house to be selected at best suitable sites. One (1) bench mark shall be monumented for each selected site based on the following item 5.2 Monumentation.

1/500 scale topographic survey is required to connect at least two existing control points, which were already established by the Government of Malaysia to serve as the origin for horizontal coordinates. Traversing and levelling for 1/500 scale topographic survey should follow the Specifications as described under 5.3 Traversing and 5.4 Levelling.

Topographical features, vegetation limits, and all the changes of the ground condition (knick points) necessary for 1/500 scale topographic mapping shall be observed by such a method as the Total Station Method. In case the boulders larger than 3 m in diameter be found in the river bed, their locations, features and elevation of top surface should be shown on 1/500 scale planimetric maps separated the topographic maps. Sufficient information shall be observed to enable 1 metre contours to be plotted on the map. Results of these field surveys shall be plotted. And the plotting accuracy shall be 0.3 mm on the map. The topographic maps shall be prepared at 1/500 scale with the standard contour line interval of 1 metre. The format of the manuscript sheet is 80 x 60 centimetres.

## 5.2 Monumentation

Monuments of bench marks shall be established at places suitable for maintenance and future use, and monumentation is to be carried out before traversing survey in conformity with Malaysian specifications (monument type, size, materials, and other detailed specifications).

## 5.3 Traversing

Traversing is required to originate at one of the existing control points which were already established by the Government of Malaysia (Land & Survey Kota Kinabalu) to serve as the origins for horizontal coordinates for traversing and closed to another one.

(1) Point Selection

Point selection shall be done as follows:

(a) Turning points shall be installed so that their intervals are as equal in distance as possible.

(b) Reference piles shall be installed for each bench mark considering possible damage to be done to the point.

(2) Horizontal Angle Observation

Horizontal angles shall be observed as follows:

(a) The direction method shall be adopted unless specified otherwise by Engineer.

(b) A pair (one set) of observation consists of two readings by telescope in the direct and in the reverse positions.

(c) Two sets of observation at 0 degree and 90 degree positions shall be carried out for each point.

(d) Allowances are as follows:

| | Allowance of double angle differences | Allowance of difference of observation |
|---|---|---|
| Horizontal angle | 30" | 20" |

(3) Vertical Angle Observation

One set of vertical angle observation consisting of reading by telescope in the direct and in the reverse shall be carried out for each sideline.

(a) Allowances are as follows:

| | |
|---|---|
| Allowance of constant of elevation | 30" |

(4) Re-measurement

In case that any of horizontal observation results exceeds the allowances as specified in the above table, all observations involved at that particular position shall be redone.

(5) Measurement of Distance

Distance shall be measured as follows:

(a) In case of using electro-optical instrument, one set of observations consists of four readings for the direct reading instrument (digital count), and for the indirect reading instrument, one set consists of readings with all modulated frequencies.

(b) Required number of sets and allowance of difference of observation are shown in the following table.

| | |
|---|---|
| Number of sets | 1 |
| Allowance of difference of observation | 4 centimetres |

Results of surveying and records, and sketches including distances from more than two distinct ground features are filled in the description form with two snap-photos of the bench mark. One is close-up and the other is a distance view.

(6) Computation and Data Sorting

(a) Coordinates computation for traversing shall be carried out in accordance with the local coordinate system (Rectified Skew Orthomorphic) and the Everest Spheroid, and the forms of point descriptions shall be provided by Engineer.

(b) Calculation at Field

Allowance of closure and closure ratio of the obtained results at field are shown in the following table. If any of the results exceed the allowance, re-observation shall be conducted after re-checking the results.

| Closure of bearing | Closure rate of coordinate | Closure rate of height | Remarks |
|---|---|---|---|
| 20 sqr. N | 1/4,000 | 12 cm sigma S / sqr.L | |

S: Length of each leg in Km N: Numbers of angle measurement
L: Number of legs

(c) The results of surveying and records are to be bound in the order of working steps. Index maps shall be prepared on the existing topographic map at a scale of 1/2,500.

## 5.4 Levelling

(1) This specification of levelling should be for determination of the elevations of bench marks by using levels and staves (direct levelling), and levelling is required to originate at more than two existing control points and checked both at the start and the end of each levelling route.

(a) The lines of sights shall not exceed 70 metres. Backsight and foresight shall be balanced at each instrument set up in order to cancel the residual instrument collimation errors.

(b) The observer shall take readings disregarding 10 centimetres at both ends of the staves.

(c) Levelling routes shall be in closed loops or an open levelling by duplicate measurements may be recommended.

(d) Temporary bench marks shall be established approximately at 4 kilometres interval on the levelling routes. They are selected and painted at suitable places such as bridges, buildings, revetments, weirs, rocks or so on, that are easy to support.

(2) Calculation

| | |
|---|---|
| Accuracy of observation | |
| Closure of loop | 5 cm x sq. root S |
| | S: length of single run in km |

(3) Index maps of bench marks and levelling routes shall be prepared on the existing topographic map at a scale of 1/2,500.

## 6. Items not Specified in this Specifications

The items not specified in this Specifications shall be instructed by the Engineer as a variation order.

## 7. Final Products to be Delivered:

(1) One (1) set of result of 1/500 scale topographic survey

(a) Observation notes
(b) Computation sheets
(c) 1/500 scale manuscript sheets

(2) One (1) set of result of traversing

(a) Observation notes

(b) Computation sheets

(c) Final computation result

(d) Descriptions of traversing point

(e) An traversing point index map

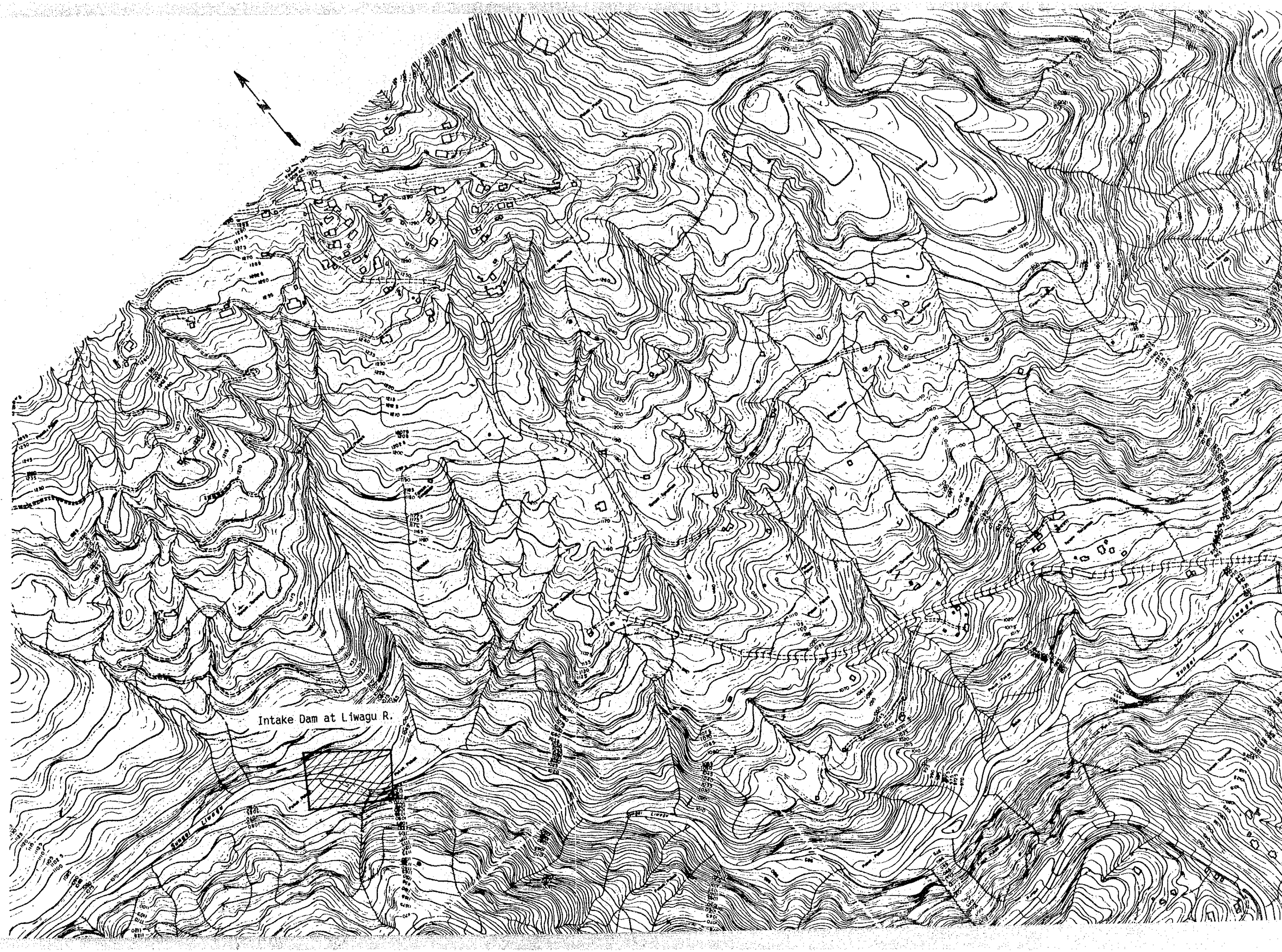
(3) One (1) set of result of levelling survey

(a) Observation notes

(b) Computation sheets

(c) Description of bench marks

(d) A levelling route index map


Intake Dam at Liwagu R.

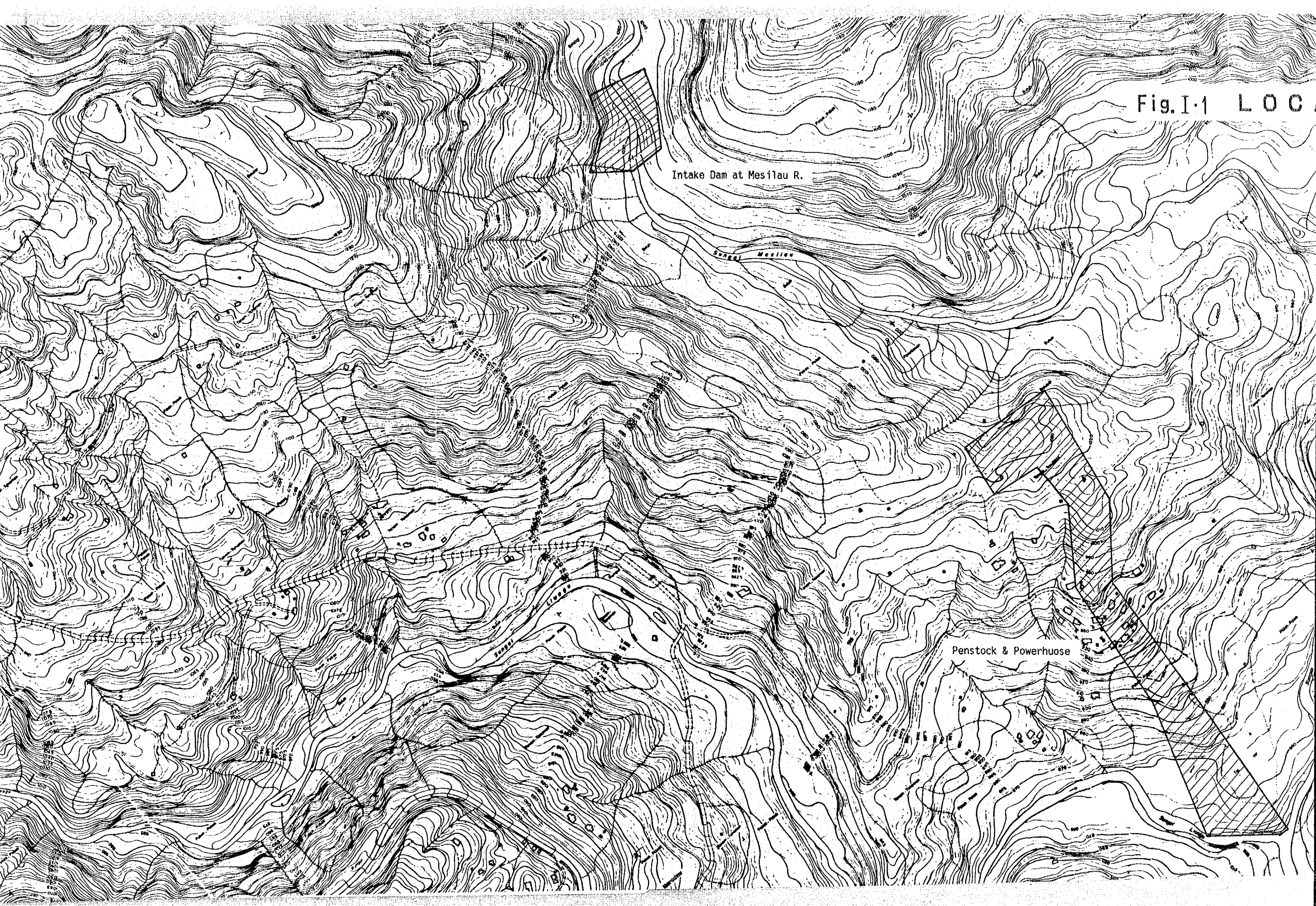
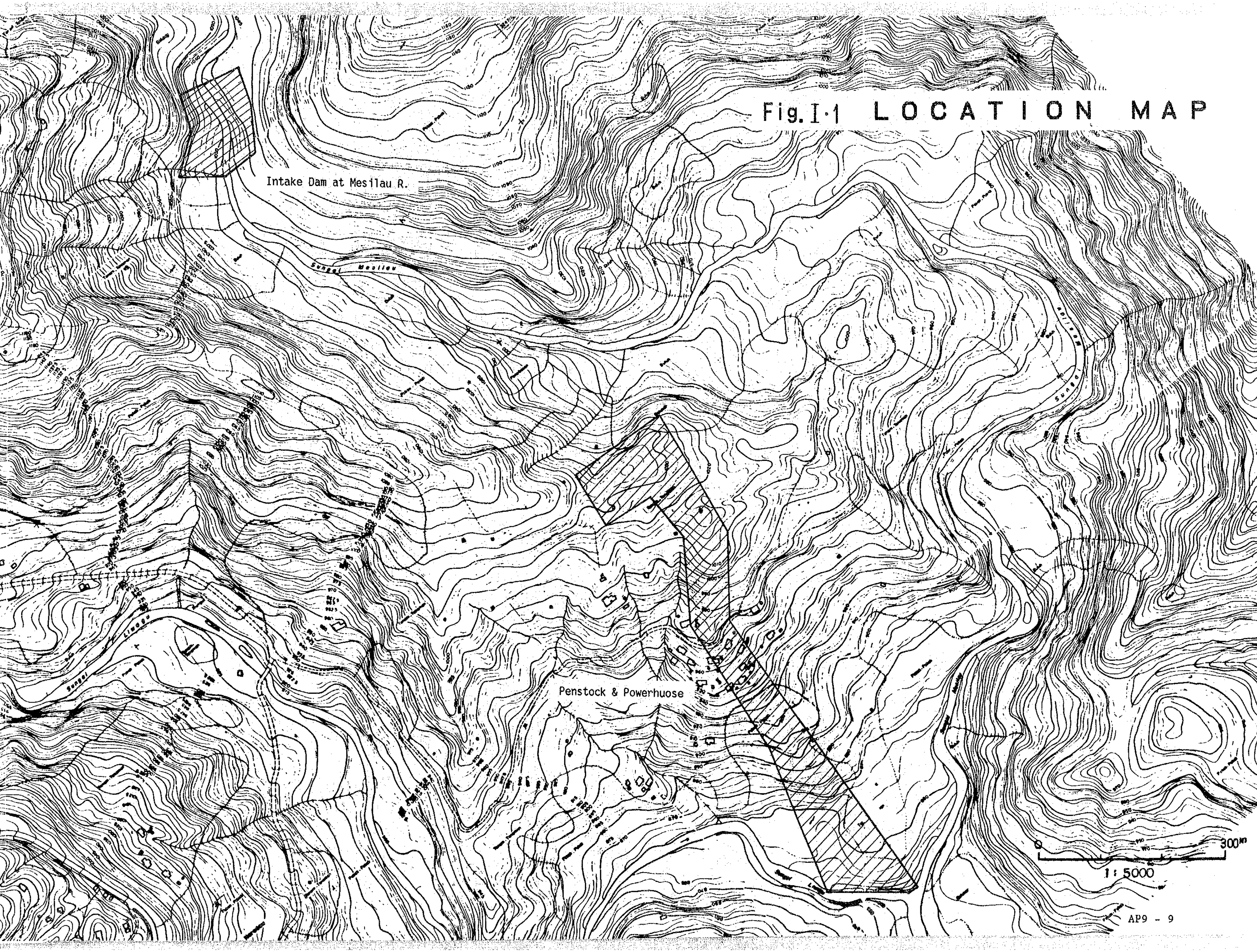
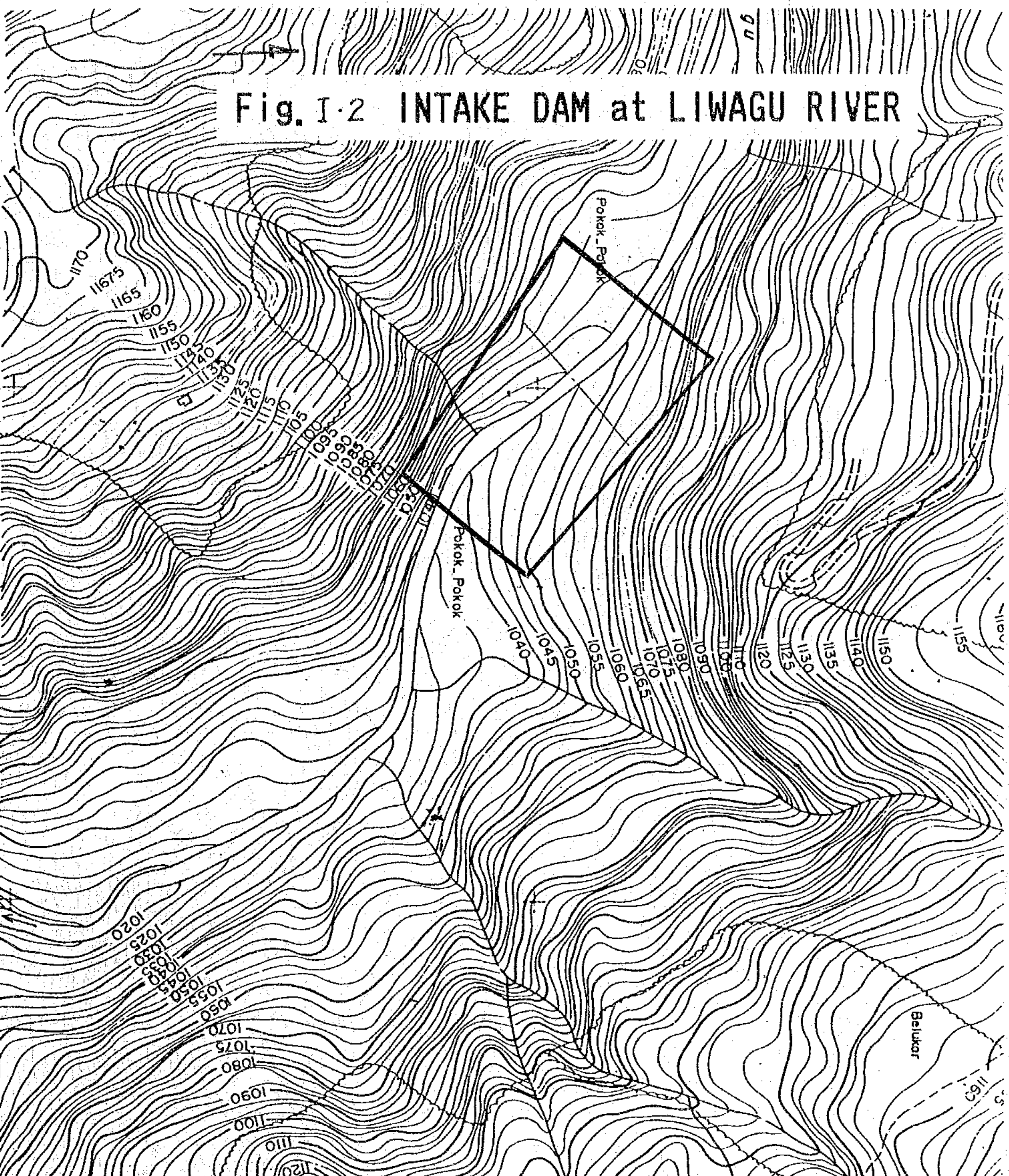


Fig. I·1 LOC
Intake Dam at Mesilau R.
Sungai Mesilau
Penstock & Powerhuose

# Fig. I·1 LOCATION MAP



# Fig. I-2 INTAKE DAM at LIWAGU RIVER




Oleh Jabatan Tanah dan Ukur, Sabah, Feb., 1988

# Fig. 1-3 INTAKE DAM at MESILAU RIVER