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Building what matters

Design Brief

Hamilton Harbour Waterfront Trail Shoreline Protection

City of Hamilton

Final

16 | 07 | 2020

Document No. 667030-DesignBrief_R0.docx

Executive Summary

In the spring of 2017, Lake Ontario water levels reached historical levels, exceeding the 100-year design water level of 76.0 m (IGLD) set in 2011. The City of Hamilton also experienced two significant rainfall events accompanied by strong winds from the east. The combination led to flooding and significant erosion or damage to multiple assets throughout the City.

SNC-Lavalin Inc. was contracted by City of Hamilton to investigate and propose conceptual solutions for the rehabilitation of the Hamilton Harbour Waterfront Trail shoreline protection and trail reconstruction. The Hamilton Harbour Waterfront Trail (HHWT) is a 3.4-kilometre-long multi-use asphalt trail that makes its way along the west shore of Hamilton Harbour from Bayfront Park through the Desjardins Canal and continues to Princess Point.

SNC-Lavalin coastal engineering team in collaboration with the civil/structural engineering team are providing two budgetary design alternatives for the trail considering the adaptation to extreme events. In addition, two shoreline protection alternatives are provided considering non-conventional design approaches.

The summary of the shoreline design options is presented below:

- Option 1 considered a conventional revetment with a berm to reduce wave energy and crest elevation.
- Option 2 consists of a submerged habitat reef (breakwater) to break the waves and provide protection to the trail shoreline. The rock size and trail elevation are reduced when compared to Option 1.
- Option 3 considered stepped revetment which can reduce the wave overtopping by introducing the slope roughness.
- Option 4 is an alternative to Option 2 shoreline protection. Using the protection from the submerged reef, this option includes the creation of a perched beach with gravel or sand material. Considering that the reef is not continuous, the perched beach would be created for selected sections of the shoreline.

The design water level for these conceptual solutions considered measured data from three stations and the recent levels from spring 2017 and 2019. A numerical wave model (CMS-Wave) was conducted to understand the extreme wave conditions at the site and estimate the design wave for the shoreline protection.

The proposed trail alignment will be kept in the same location as the existing for this study. Trail construction cost including earthworks are estimated for the two main design options.

The proposed main design options were reviewed, and complimentary structural designs were developed and evaluated to protect the trail as well as keep it within the project limits. With these design options, retaining walls will be required along the west edge of the trail. The associated costs for the construction of the retaining walls are estimated for each option and included in the overall costs of the trail protection options.

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1. Introduction

1.1 Overview

The Lake Ontario water level rise and the co-incident wind/wave storms are the main cause of the observed shoreline damage and erosion of the City of Hamilton shoreline assets. As part of the comprehensive study of the shoreline protection, SNC-Lavalin Inc. (SNCL) was retained by City of Hamilton to provide engineering conceptual design for shoreline protection solutions to the Hamilton Harbour Waterfront Trail (HHWT) including raising the trail elevation to consider the current extreme water levels at Lake Ontario. The design was developed by SNCL's coastal engineering team in collaboration with the civil and structural team.

The HHWT is a 3.4-kilometre-long multi-use asphalt trail that makes its way along the west shore of Hamilton Harbour from Bayfront Park through the Desjardins Canal and continues to Princess Point. The trail connects to the Trans Canada Trail, the Lake Ontario Waterfront Trail in Burlington, and the Desjardins Canal bordering Cootes Paradise.

The 2-kilometer section of trail spanning from Bayfront Park to the floating bridge located within the Desjardins Canal is the focus of this design.

Figure 1 shows the trail location.

Figure 1: View of Hamilton Harbour Waterfront Trail

1.2 Metocean Conditions

Metocean (meteorological and oceanographic) conditions at the site were assessed in Ref.[2]. This reference is the basis for the definition of existing and future metocean conditions at the site.

1.2.1 Winds

Wind analysis has been performed by SNC-Lavalin during the Shoreline Inventory and Assessment of the City of Hamilton owned assets (Ref.[2]). Among the three measurement stations considered in the area (Hamilton A, Burlington Piers and C45139 (West Lake Ontario), Hamilton A station was selected as the most representative station for extreme wind analysis since the period of measurement is longer than the other stations, which increases the reliability of the results. Figure 2 shows the annual wind rose from Hamilton A station for the past 48 years (1970-2017). The maximum wind speed observed during the past 48 years (1970-2018) was approximately 31 m/s and calm conditions occurred in approximately 3% of the records.

Table 1: Bivariate histogram wind speed and direction Hamilton A Station (1970-2018)

	UDir (from deg T)																
U (m/s)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
>20.0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0%
15.0 - 20.0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0%
10.0 - 15.0	0.0%	0.1%	0.4%	0.5%	0.0%	0.0%	0.0%	0.0%	0.1%	0.3%	0.7%	1.0%	0.7%	0.2%	0.1%	0.0%	4%
5.0 - 10.0	1.0%	1.4%	3.3%	3.3%	0.7%	0.1%	0.1%	0.2%	1.4%	3.3%	4.5%	5.4%	5.1%	2.6%	1.8%	0.9%	35%
0.0 - 5.0	3.0%	3.0%	4.8%	4.4%	3.0%	1.0%	0.9%	1.4%	4.0%	4.6%	5.6%	6.1%	7.4%	3.4%	2.6%	2.0%	57%
< 0.0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0%
Calm																	3%
Total	4.0%	4.6%	8.5%	8.3%	3.7%	1.1%	1.0%	1.6%	5.4%	8.1%	10.9%	12.7%	13.2%	6.2%	4.5%	3.0%	100%

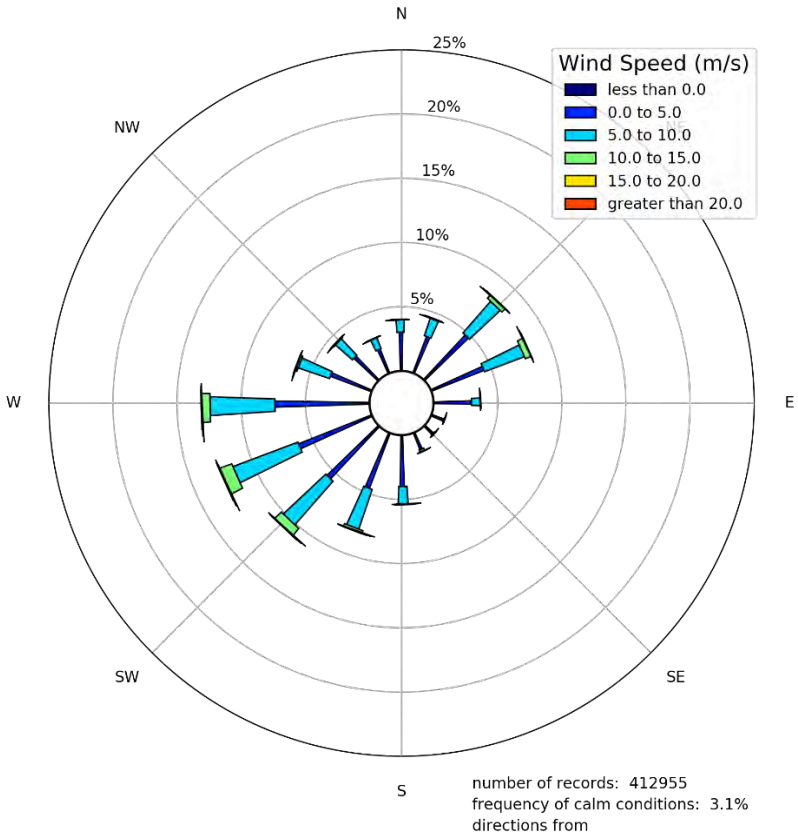


Figure 2: Wind Rose from Hamilton A Station (1970-2018) (Ref [2])

Wind speeds with Annual Exceedance Probability (AEP) of 1:10, 1:25, 1:50, and 1:100 were calculated for directions NE, E and SE. Table 2 shows the extreme wind analysis for the wind directions of interest. More detailed information about these wind stations data can be found in Ref.[2].

Table 2: Extreme wind speed by direction for Hamilton A Station (Gumbel)

AEP	NE	E	SE
1:10	20.2 (18.4 to 21.9)	16.7 (15.5 to 17.9)	1.8 (9.8 to 11.9)
1:25	22.4 (20.0 to 24.7)	18.2 (16.6 to 19.7)	12.2 (10.8 to 13.5)
1:50	24.0 (21.2 to 26.8)	19.2 (17.4 to 21.1)	13.1 (11.5 to 14.8)
1:100	25.6 (22.3 to 28.8)	20.3 (18.1 to 22.5)	14.1 (12.2 to 16.1)

A wind wave numerical model was conducted to determine the deep water design wave conditions at the HHWT. The extreme wind events with AEP of 1/100 from NE (26 m/s) and E (20 m/s) were considered as model inputs.

1.2.2 Water Levels

The water levels were obtained from three stations in close proximity of the area of interest. Figure 3 shows the location of the stations.

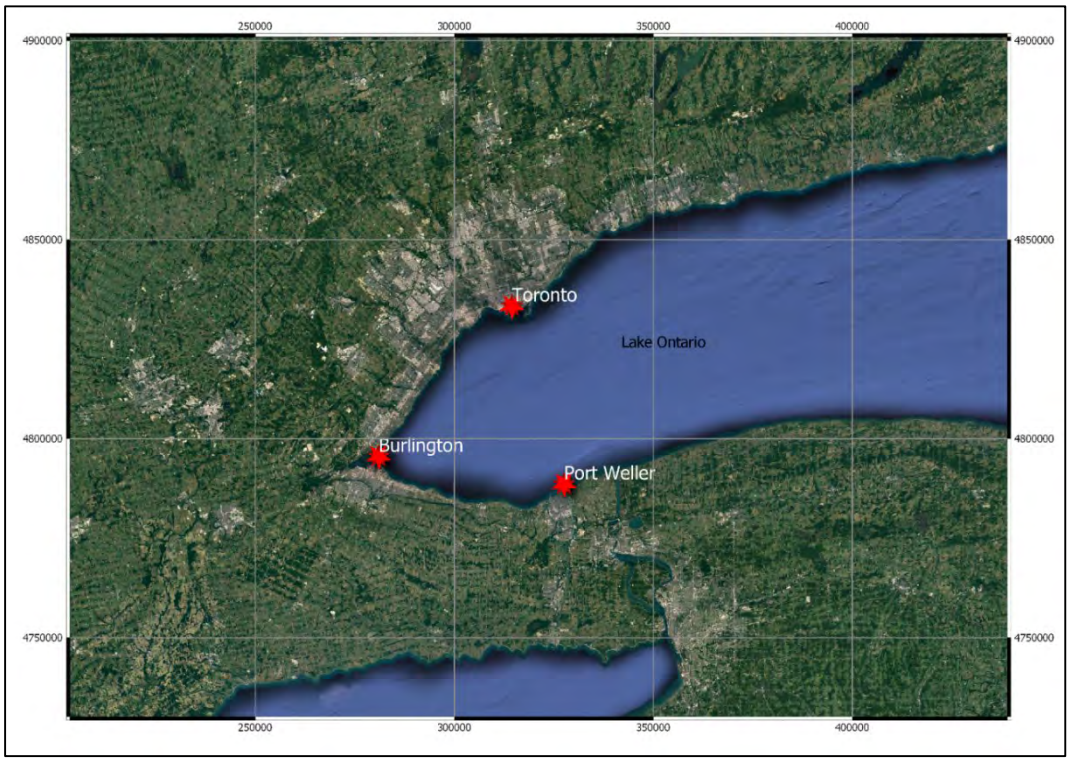


Figure 3: Location of the Water Level Stations

The extreme value analysis was conducted for the three stations. The Burlington station is the closest to the site of interest; however, only 11 years historical record is available in this station. Port Weller and Toronto stations have historical water level data of 58 years (1962-2019), thereby the extreme value analysis is more reliable in these stations. Figure 4 indicates the annual maximum water level over the last 11 years.

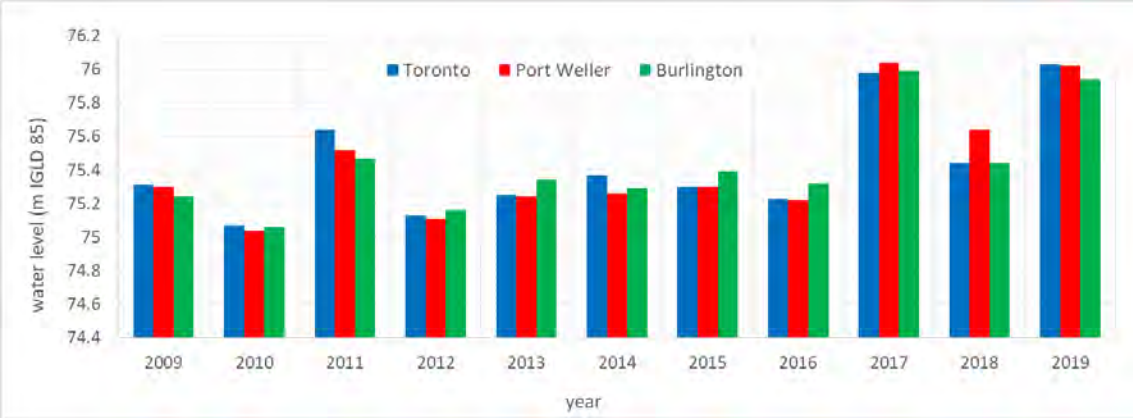


Figure 4: Historical Maximum Measured Water Level

The maximum water level of 76.04 m was registered at Port Weller station in 2017.The annual comparison of water level in Figure 4 indicates that the past few years' high-water level can be attributed to recent changes to the Great Lakes water regimes driven by climate change effects.

Table 3: Design Water Levels

Annual Exceedance Probability	Extreme Water Level Analysis (m IGLD)		
	Port Weller	Toronto	Burlington
1:10	75.7 (75.5 to 75.9)	75.6 (75.5 to 75.8)	75.8 (75.4 to 76.2)
1:25	75.9 (75.7 to 76.1)	75.8 (75.6 to 76.0)	76.1 (75.5 to 76.6)
1:50	76.1 (75.8 to 76.3)	75.9 (75.7 to 76.2)	76.2 (75.5 to 76.9)*
1:100	76.3 (76.0 to 76.6)	76.1 (75.8 to 76.3)	76.4 (75.6 to 77.2)*

*shorter time series

The 100-year flood level at 76.0 m at the Lake Ontario Shoreline is reflected in the 2011 guidelines from the Hamilton Conservation Authority (Ref.[1]).

The extreme value analysis over the records at three water level stations close at Lake Ontario (Burlington, Toronto and Port Weller) indicates that the 1:100 AEP water level varies from 74.1 to 76.4 m IGLD7 (equivalent to 2.2 m CD), see Table 3 for details. The design water level is set to 76.4 m IGLD at this conceptual level stage.

1.2.3 Currents

The wind driven currents are not expected to govern the nearshore processes at the area of interest.

1.2.4 Waves

A numerical wave model (CMS-Wave) was conducted to understand the extreme wave conditions at the site and estimate the design wave for shoreline protection.

The extreme events used for model input consider the AEP of 1:100 from NE (26 m/s) and E (20 m/s). Section 2 describes the wave model inputs and outputs.

1.2.5 Trail

The existing trail is asphalt constructed with an average width of 6 m. There are various lookout points along the trail with seating areas. For the purposes of this study, a proposal trail width of 6m will be considered. Features such as lookout points will be reserved for the detailed design.

2. Numerical Wave Model

2.1 Inputs

2.1.1 Reference system

The horizontal and vertical reference datum used in this model is given in Table 4 unless indicated otherwise.

Table 4: Coordinate system used in the wave modelling

Parameter	Value
Horizontal datum	UTM Zone 17N (NAD 1983)
Vertical datum	Chart Datum

The vertical elevations for the wave model are referenced to the Chart Datum (CD). Chart Datum is equivalent to 74.2 m International Great Lakes Datum 1985 (IGLD).

2.1.2 Bathymetry

The bathymetry used for the generation and propagation of the waves is a compilation of nautical chart (CHS N.2077), topographic and bathymetric data provided by the City of Hamilton, and SNC-Lavalin bathymetric survey sections (conducted during the spring 2019).

The three sets of data overlapped in some areas. Those areas have been checked so that the bathymetry was smooth between the different sources. The vertical elevations are referenced to Chart Datum.

Figure 5: Model Bathymetry and Output Locations

Once the new scatter set of data was merged, cleaned and checked, the bathymetry was interpolated over a uniform grid. The grid cell size of 5.0 m was selected to represent properly the existing artificial islands close to the trail.

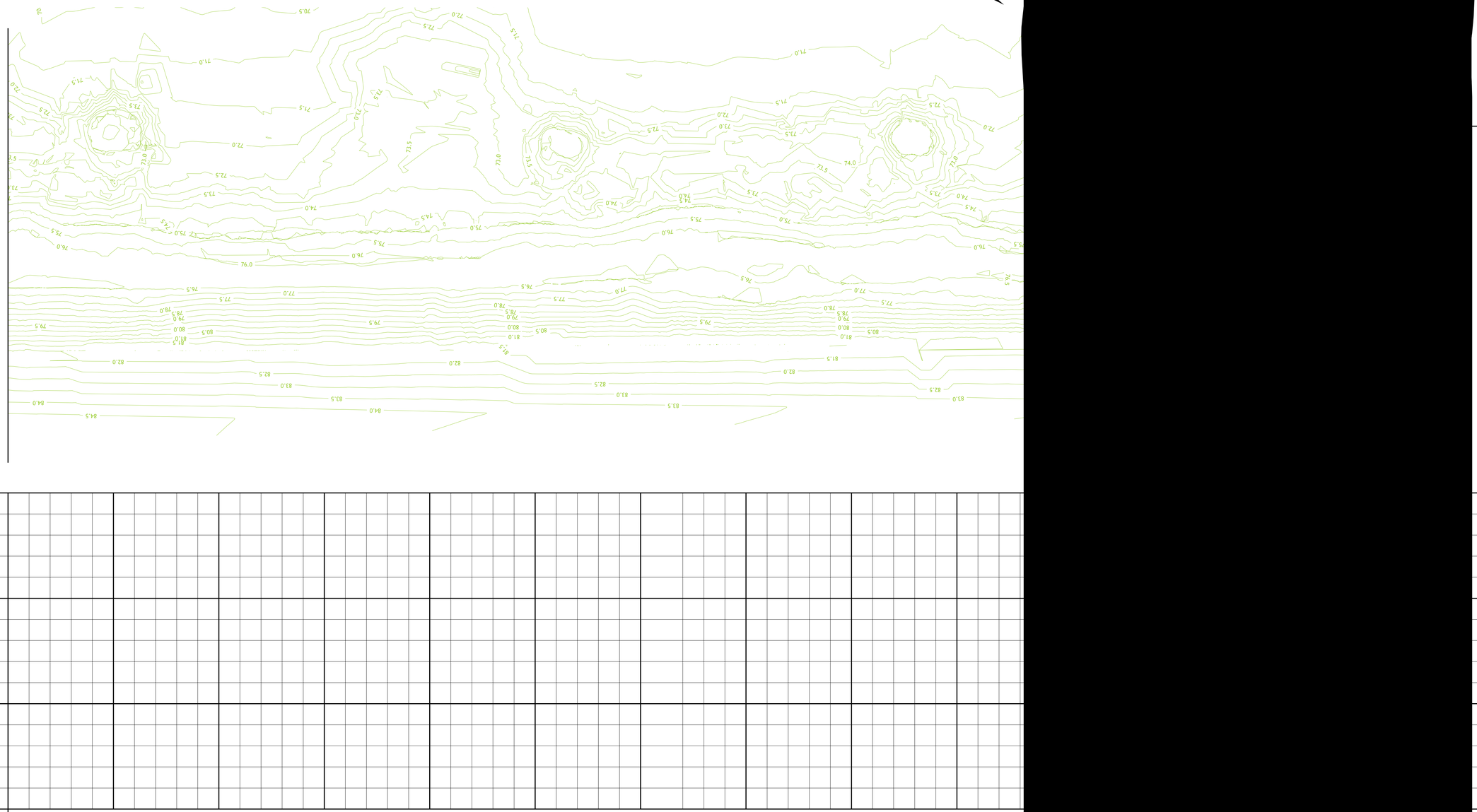
2.2 Runs

Considering that the HHWT shoreline is more exposed to directions NE and E, those were the directions used in the wave model. Table 5 shows the wind and water level conditions used in the model based on the extreme value analysis described in Section 1.2.2.

Table 5: Bathymetry, Wind and Water Level Conditions

Run case	Water Level condition [m CD]	Wind Speed (m/s)	Wind Direction (deg N)	Bathymetry
1	2.2*	26	NE	Actual
2	2.2*	20	E	Actual

*2.2 m CD equivalent to 76.4 m IGLD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71.0
71.5
72.0
72.5
73.0
73.5
74.0
74.5
75.0
75.5
76.0
76.5
77.0
77.5
78.0
78.5
79.0
79.5
80.0
80.5
81.0
81.5
82.0
82.5
83.0
83.5
84.0
84.5

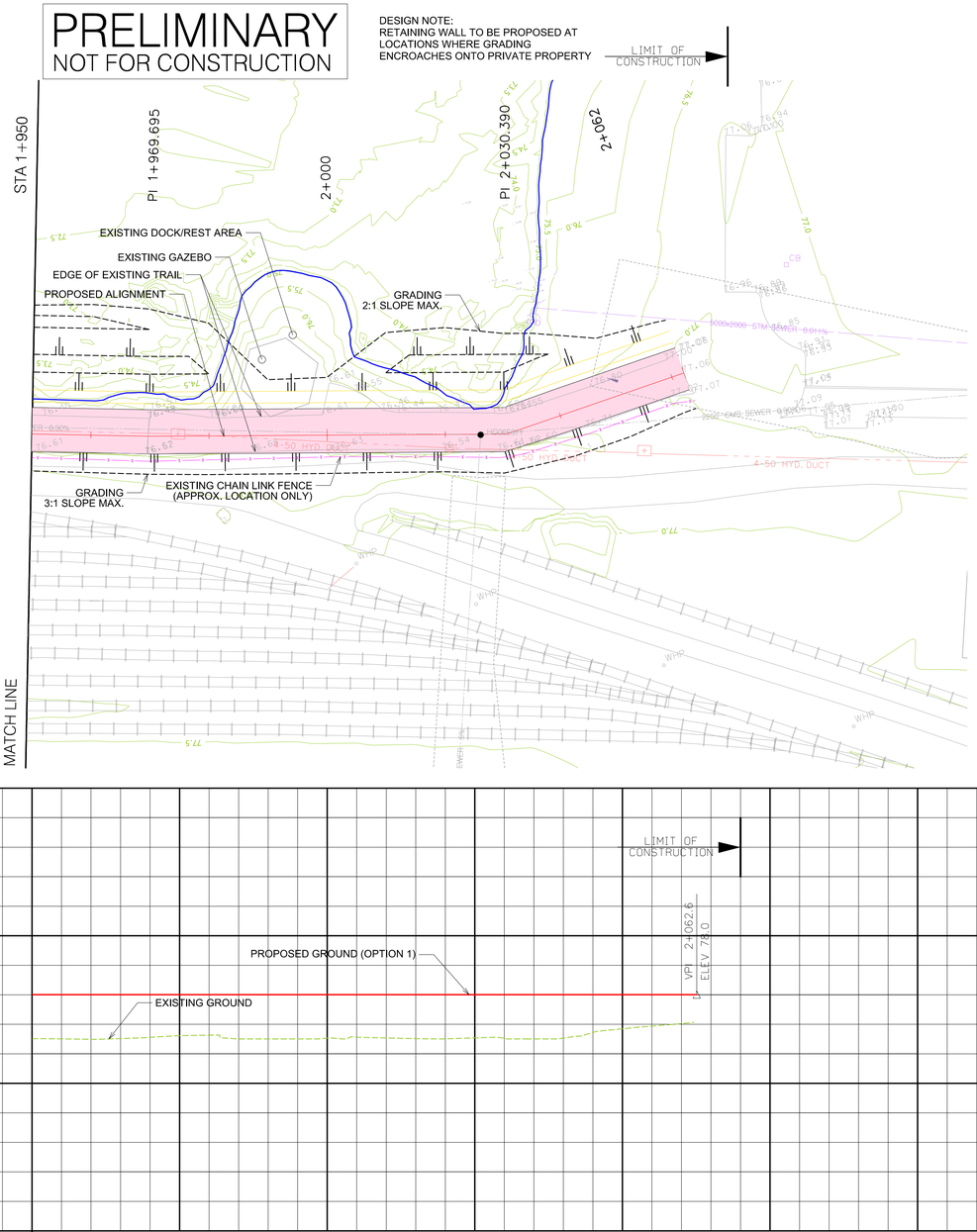
HAMILTON HARBOUR WATERFRONT TRAIL

PRELIMINARY
NOT FOR CONSTRUCTION

DESIGN NOTE:
RETAINING WALL TO BE PROPOSED AT LOCATIONS WHERE GRADING ENCROACHES ONTO PRIVATE PROPERTY

FILE No.	CONTRACT No. -	SHEET No.
	DRAWING No. -	7 OF 7

DIMENSIONS SHOWN ON THIS PLAN ARE IN METRES UNLESS OTHERWISE NOTED



PROPOSED ℄ OF TRAIL PROFILE ELEVATIONS	78.0	78.0	78.0	78.0	78.0			PROPOSED ℄ OF TRAIL PROFILE ELEVATIONS
EXISTING ℄ OF TRAIL PROFILE ELEVATIONS	76.5	76.6	76.5	76.5	76.8			EXISTING ℄ OF TRAIL PROFILE ELEVATIONS
EXISTING ℄ OF TRAIL ALLOWANCE CHAINAGE	1+950	1+975	2+000	2+025	2+050	2+075	2+100	EXISTING ℄ OF TRAIL ALLOWANCE CHAINAGE

No.	REVISIONS	INITIAL	DATE
1	PRELIMINARY TRAIL LAYOUT	N.C.	12/2019

DRAWN BY: J.P. DATE: DECEMBER 6 2019

REFERENCE MATERIAL:
Base Information : CITY OF HAMILTON

Geodetic Bench Mark Index No. X-XX Elevation=XX.XXXm
Borehole Report -

SCALES
HORIZONTAL 1:500 (0 5m 10m 20m)
VERTICAL 1:100 (0 1m 2m 4m)

DESIGNER
Stephen McDonald

PROJECT ENGINEER
Norton Chu, P. Eng.

CITY OF HAMILTON
Public Works Department

HAMILTON HARBOUR WATERFRONT TRAIL

OPTION 1 - SHORELINE PROTECTION (PROP. ELEV.: 78.0m)

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To : STATION 2+070

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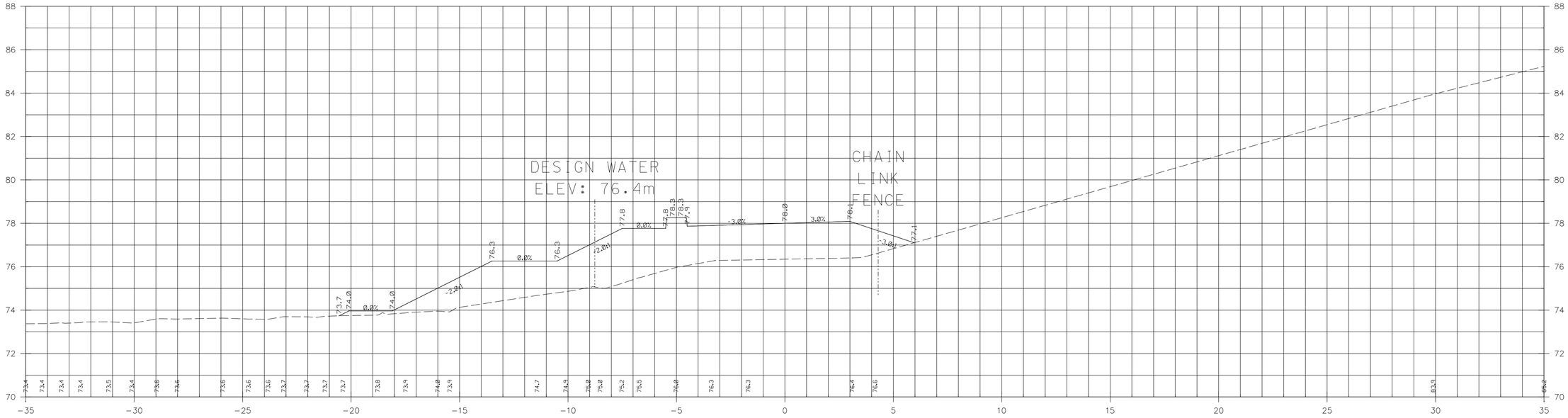

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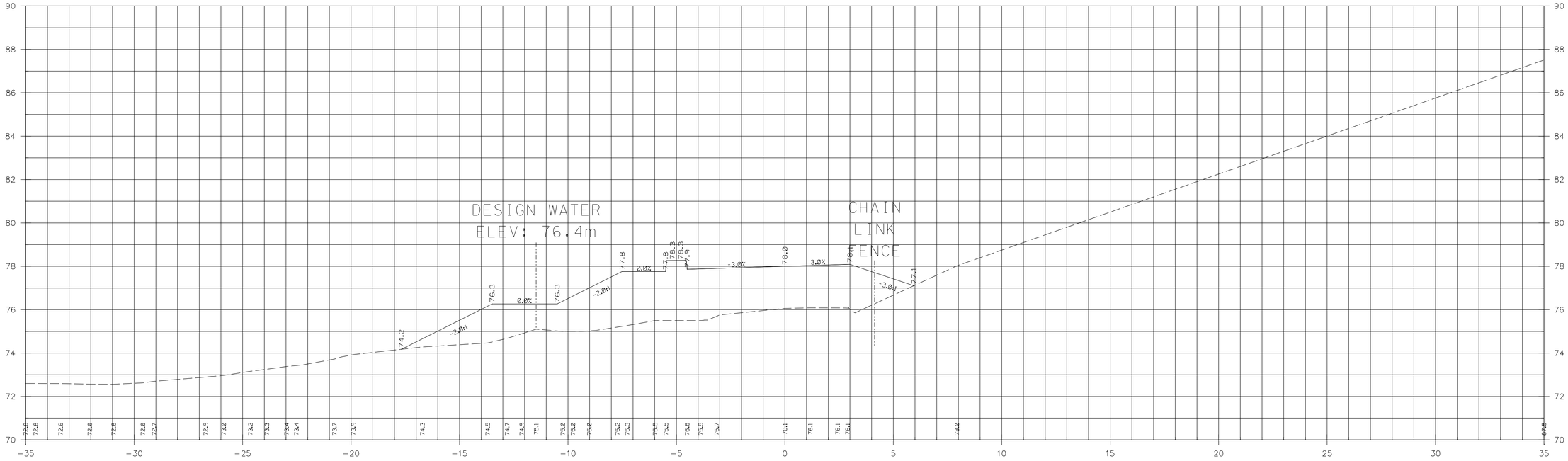

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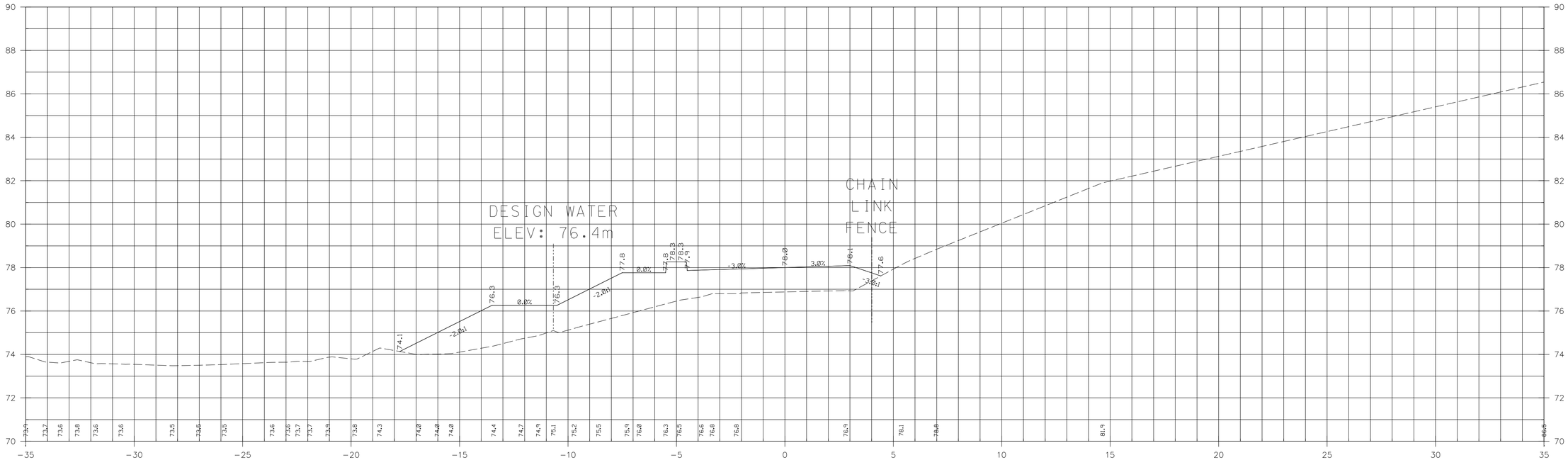

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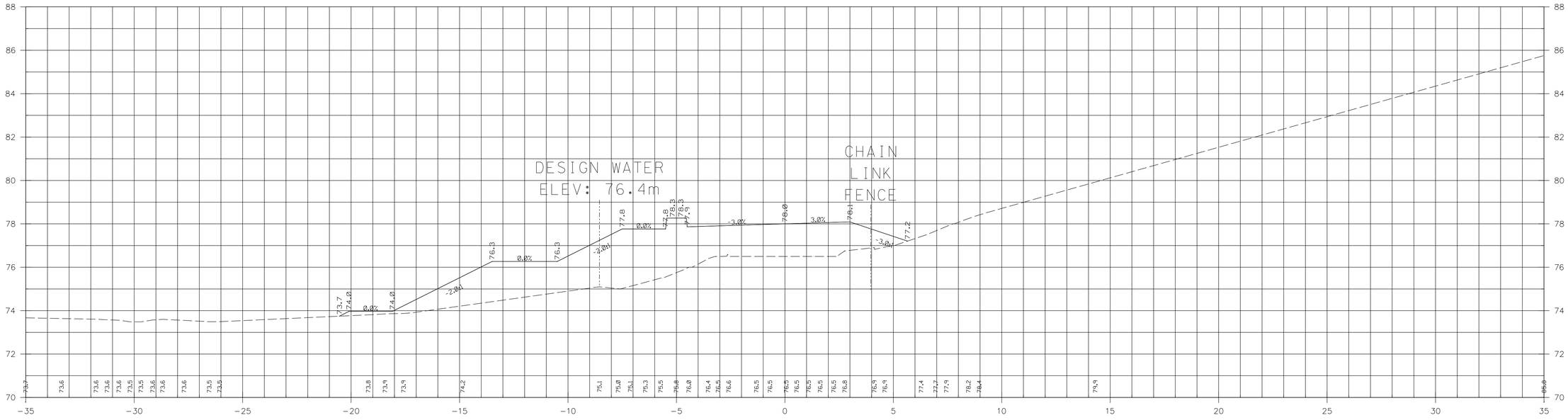

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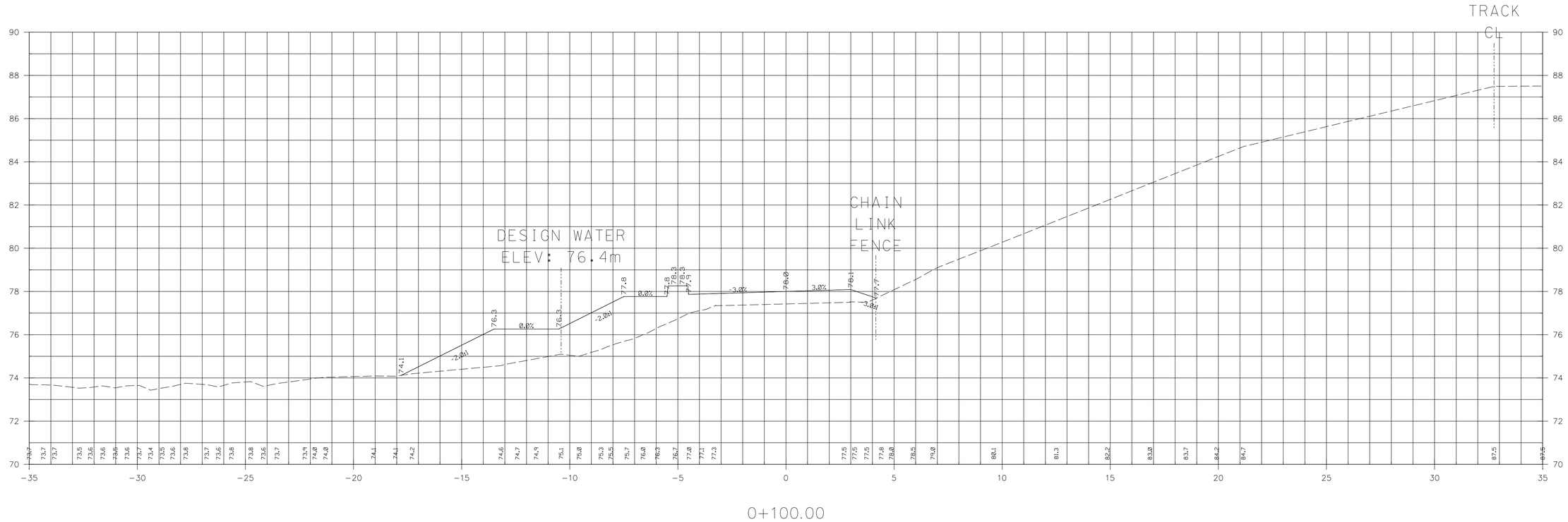

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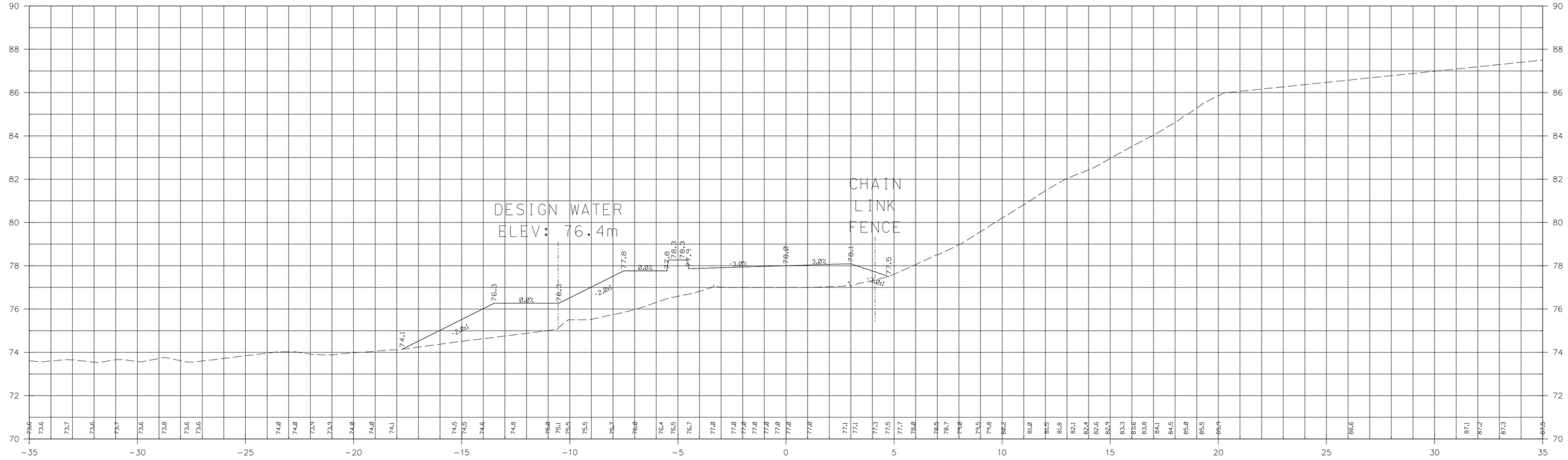

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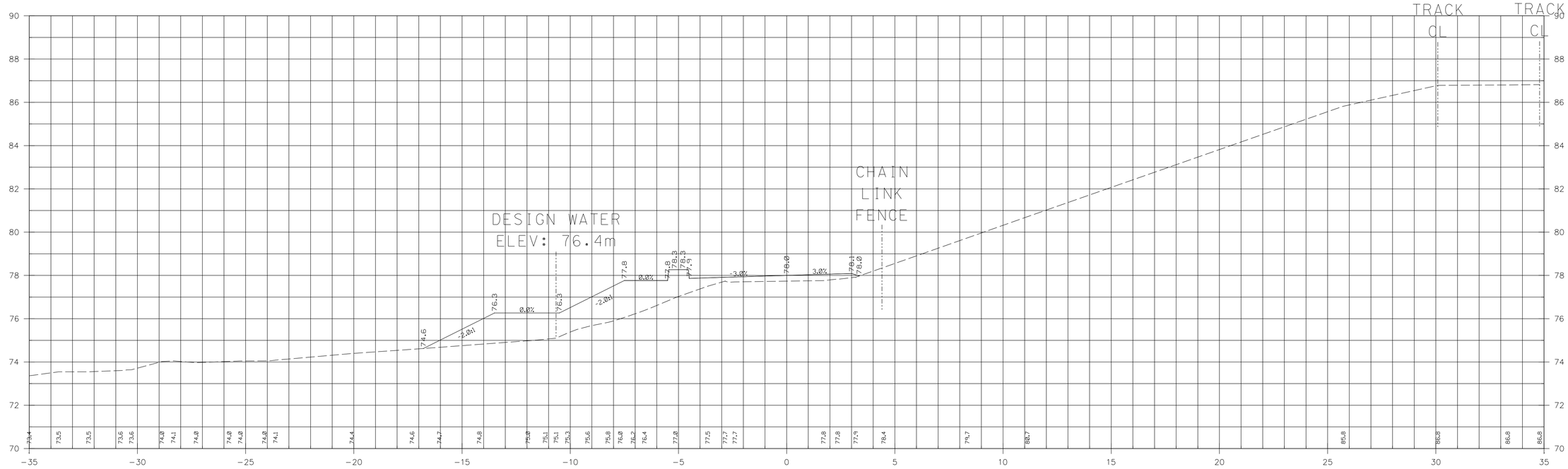

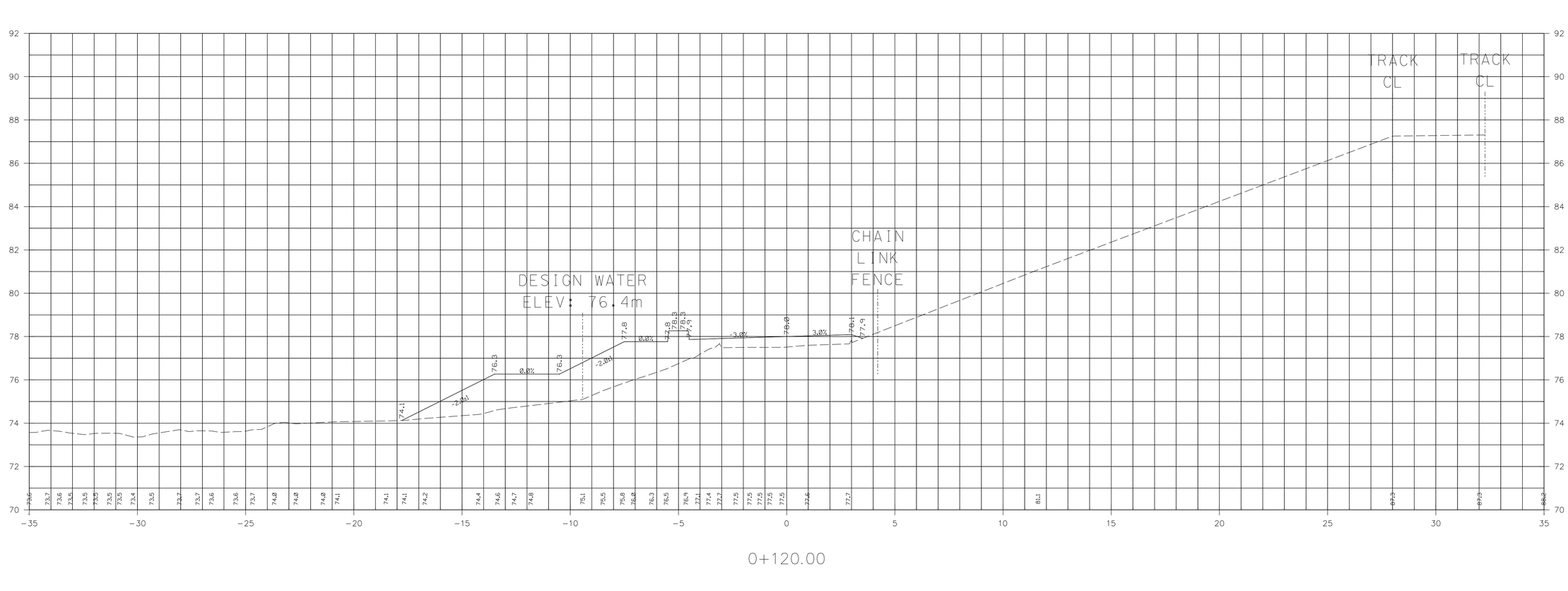

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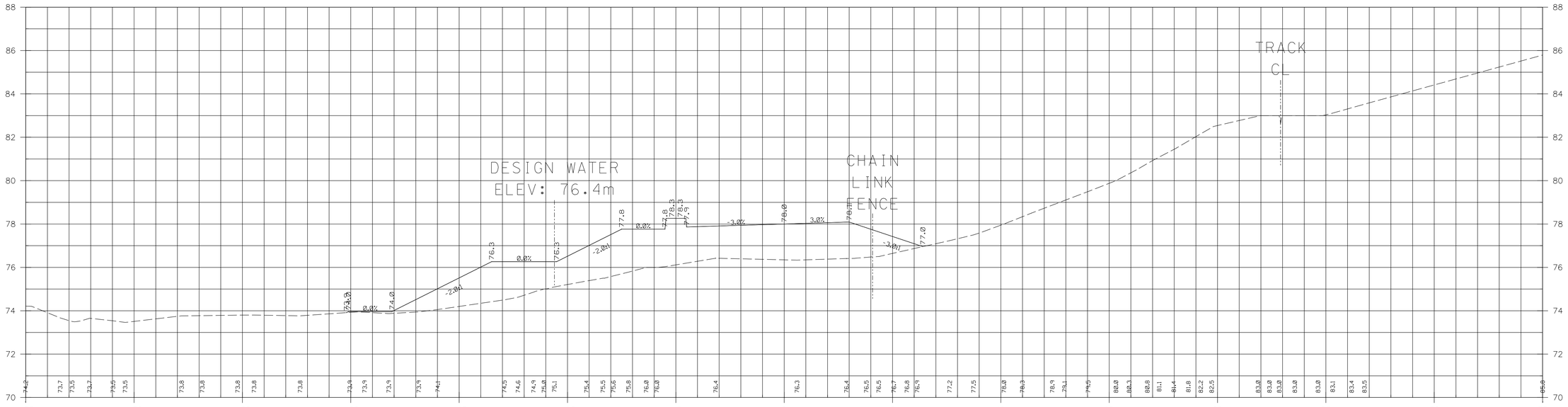

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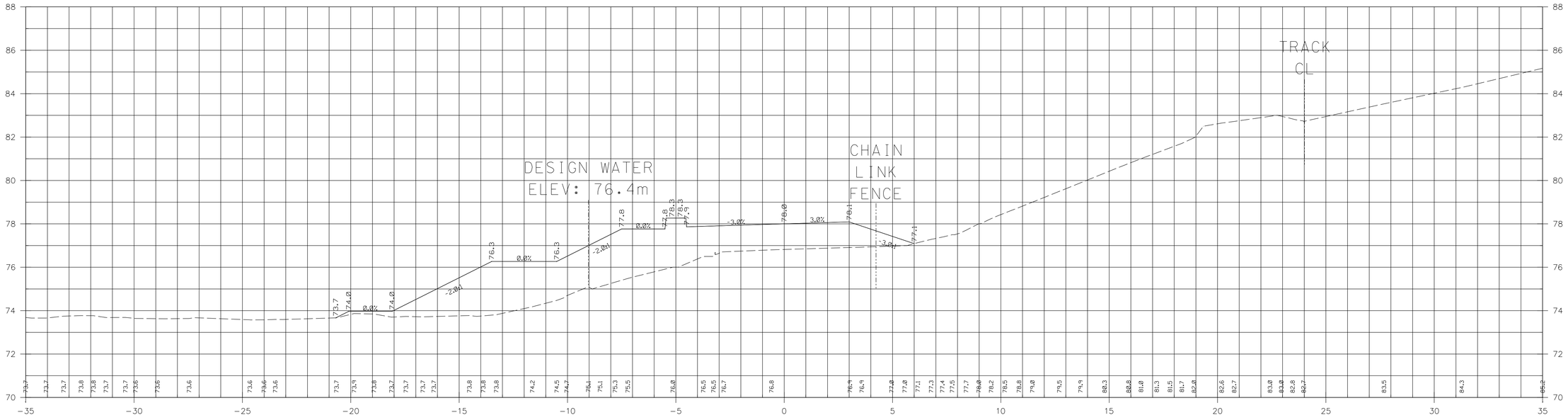

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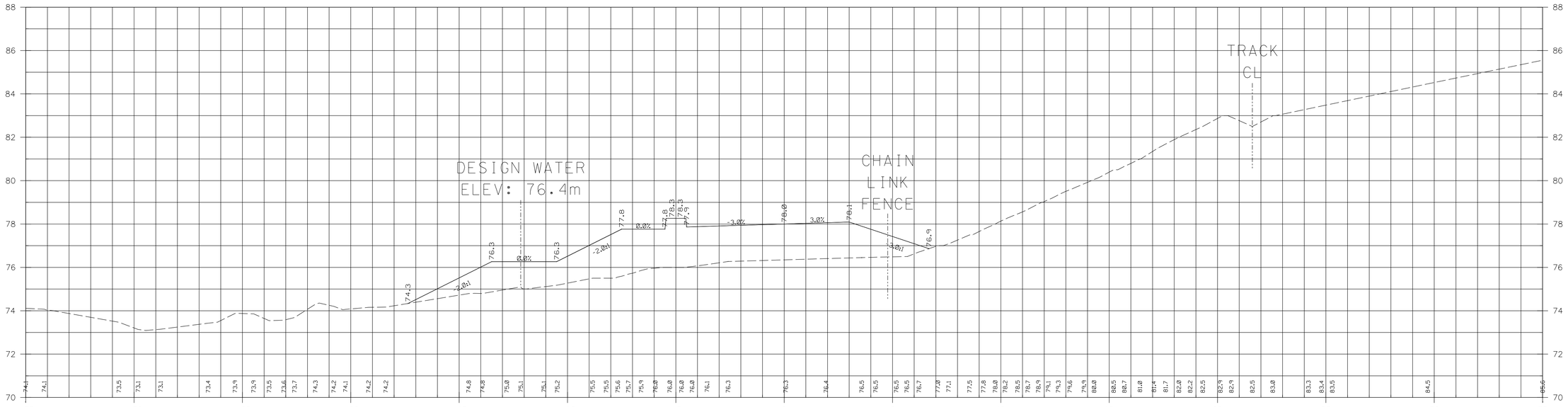

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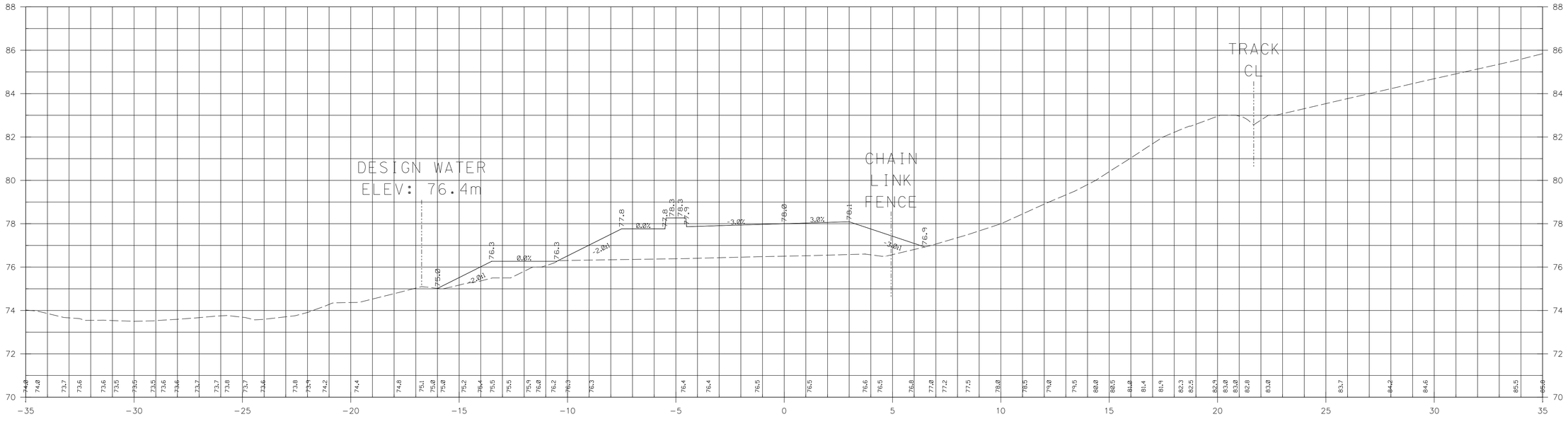

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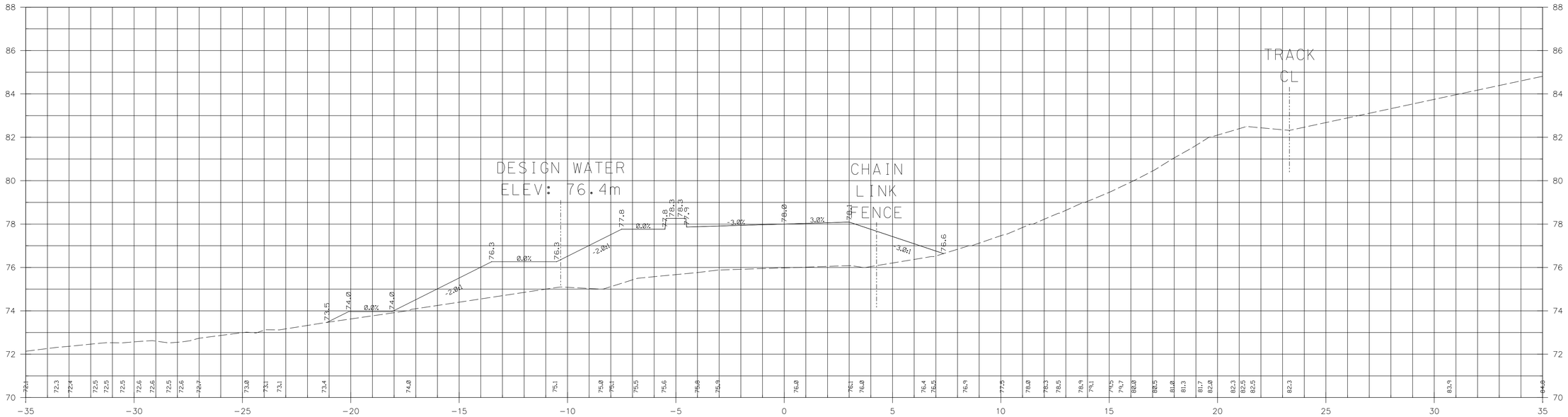

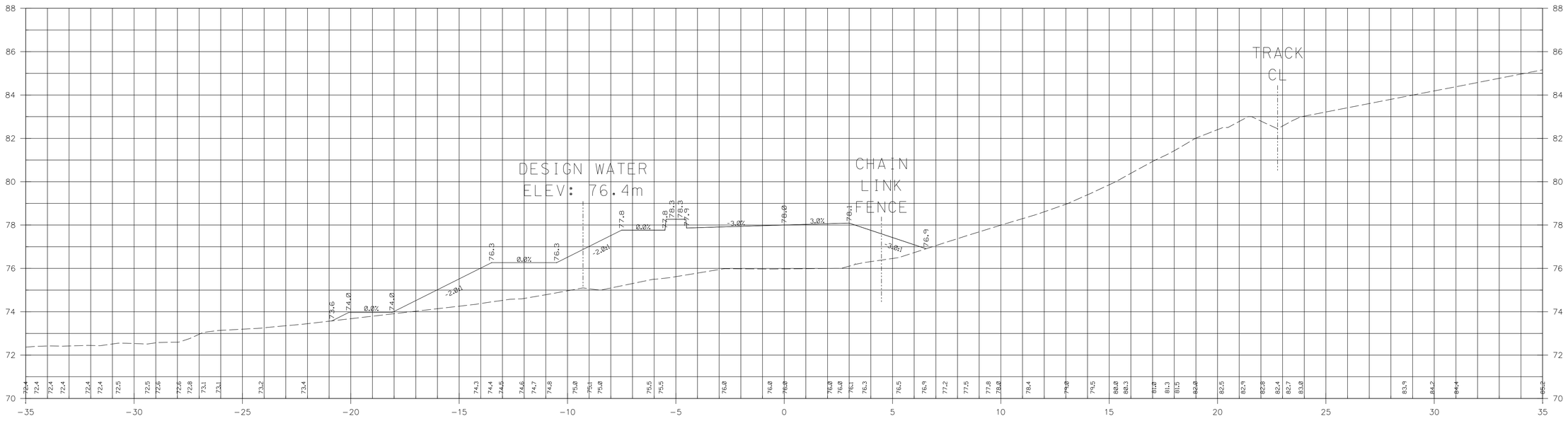

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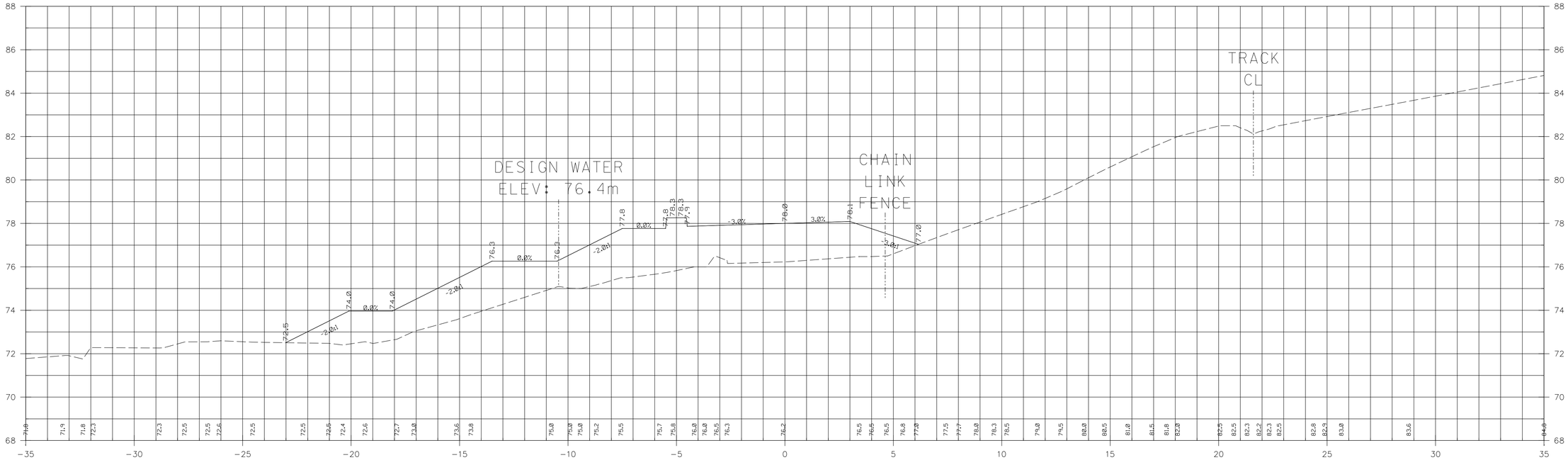

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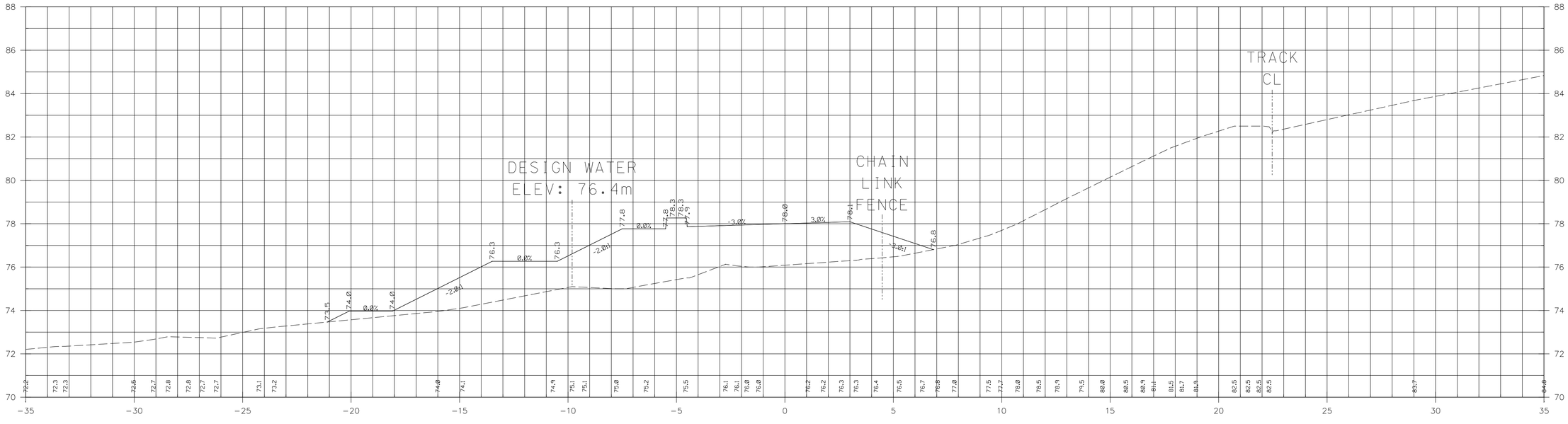

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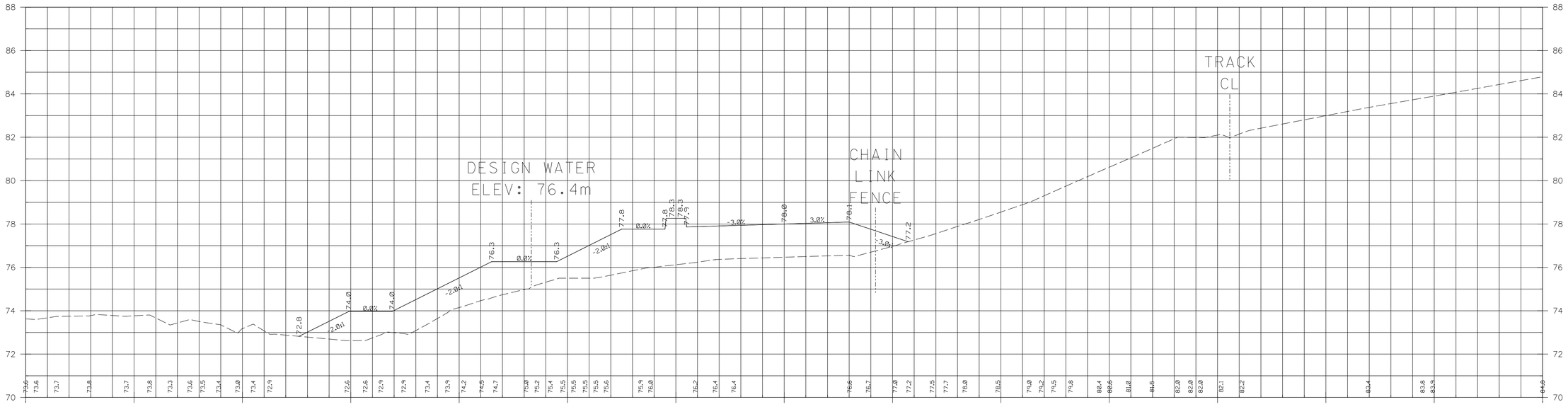

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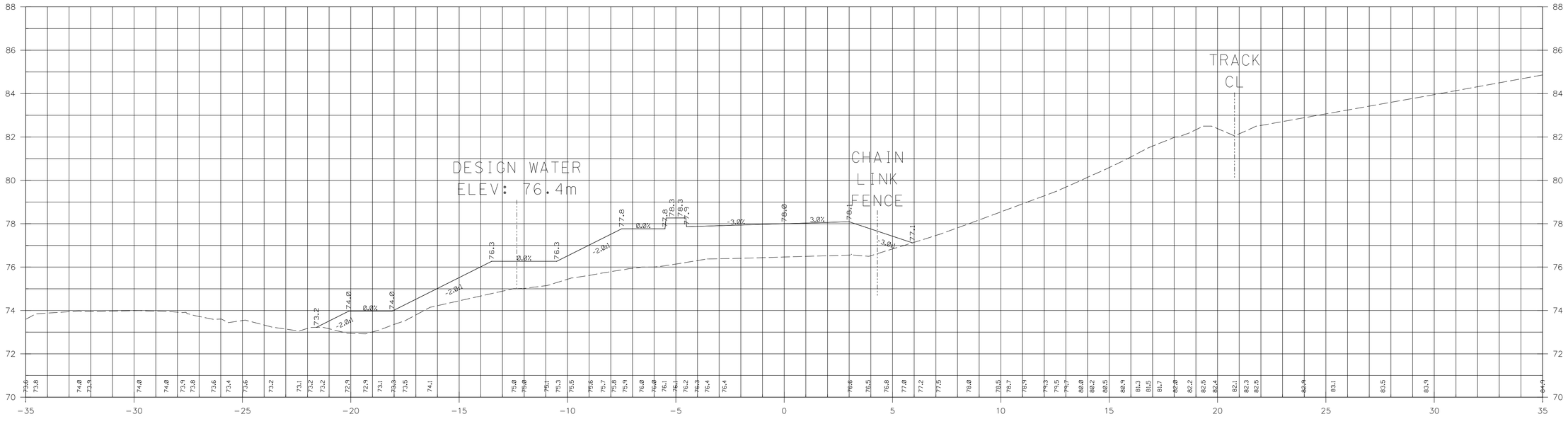

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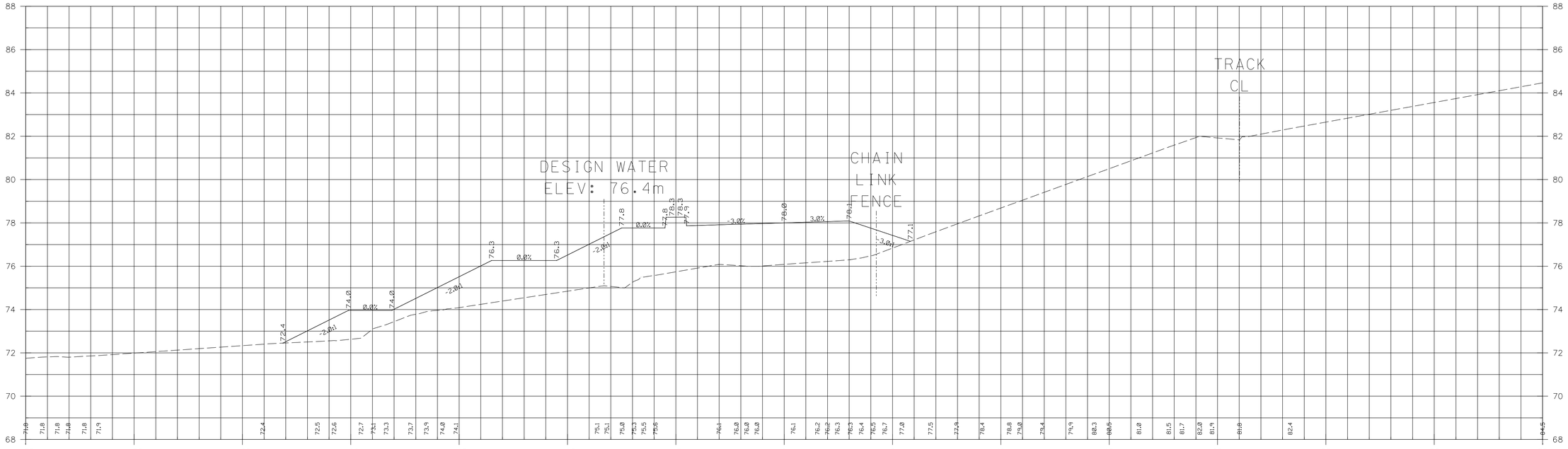

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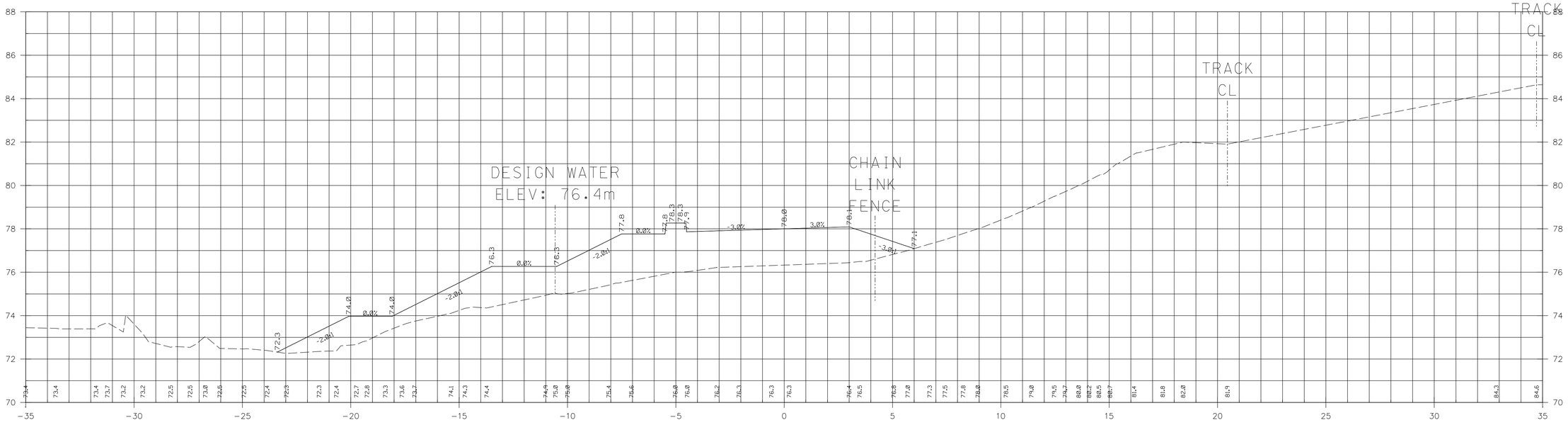

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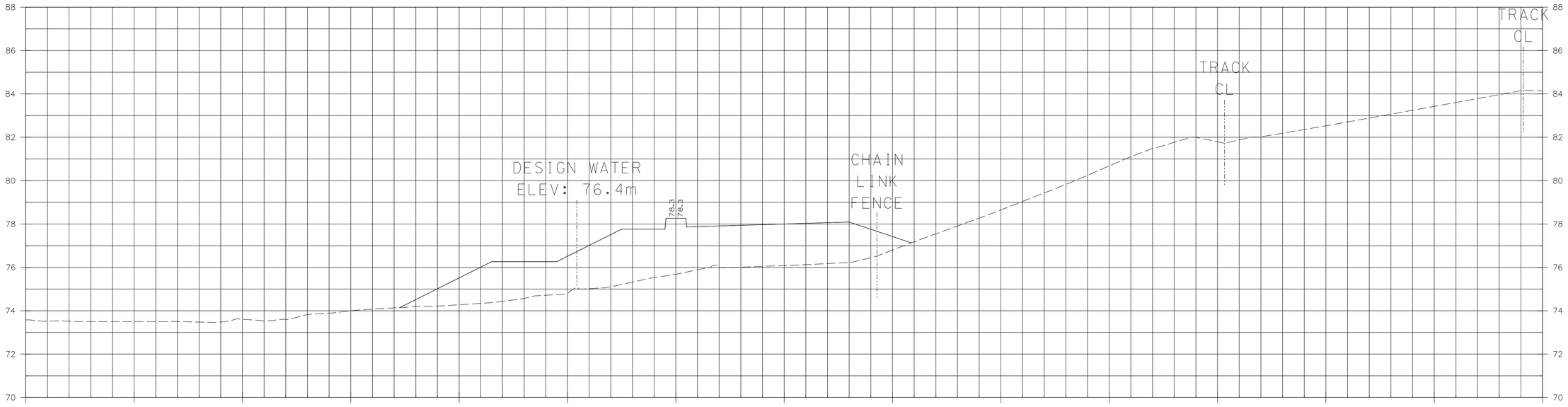
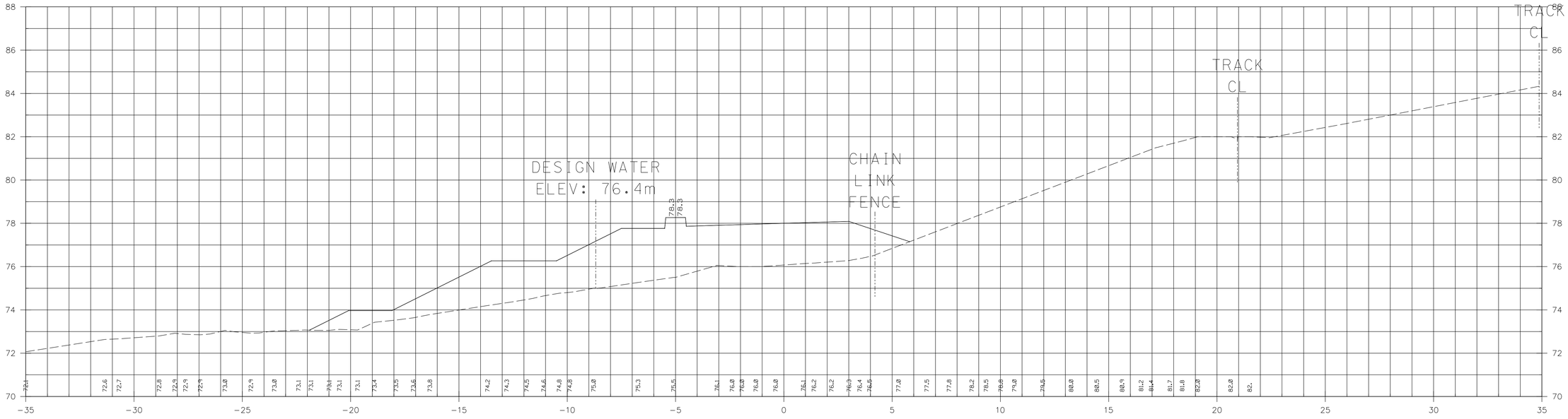
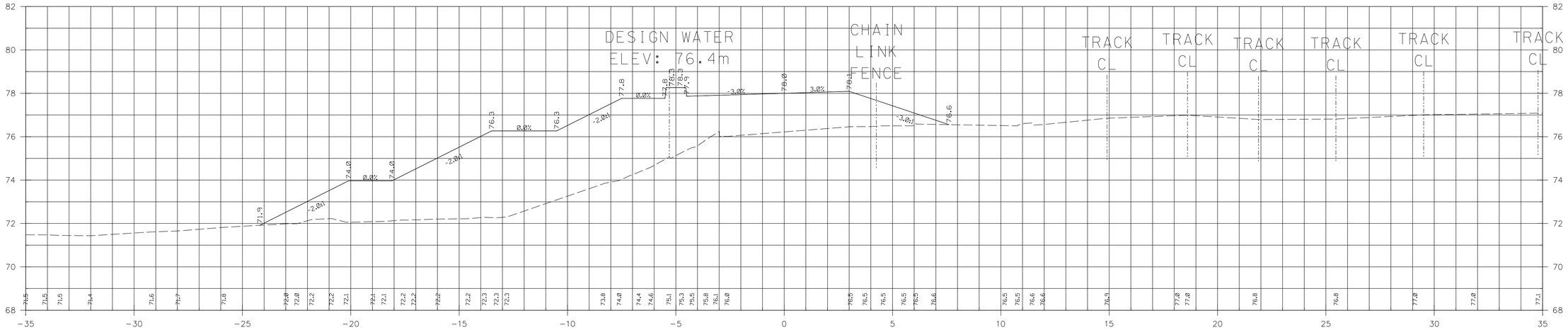


0+420.00

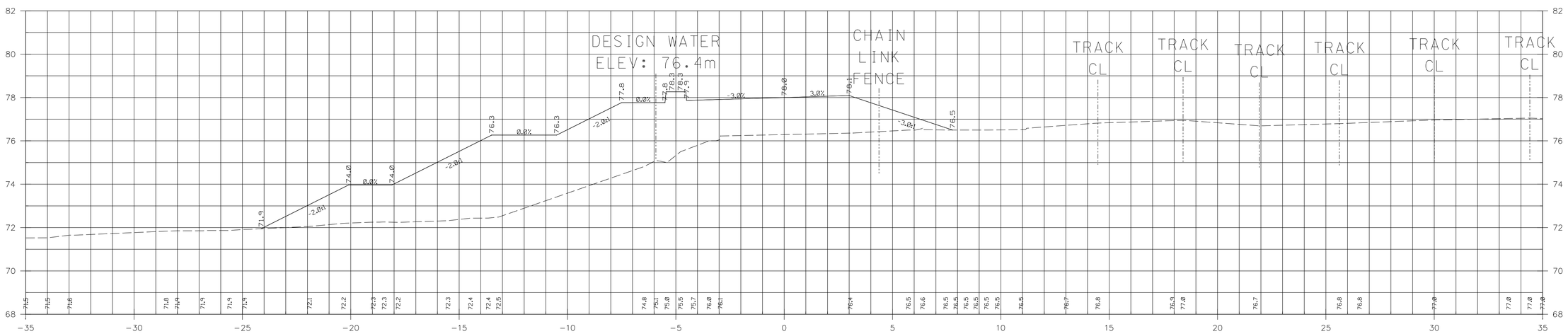


0+400.00

SCALE: 1:100 STA 1+760.00 TO STA 1+780.00



1+780.00



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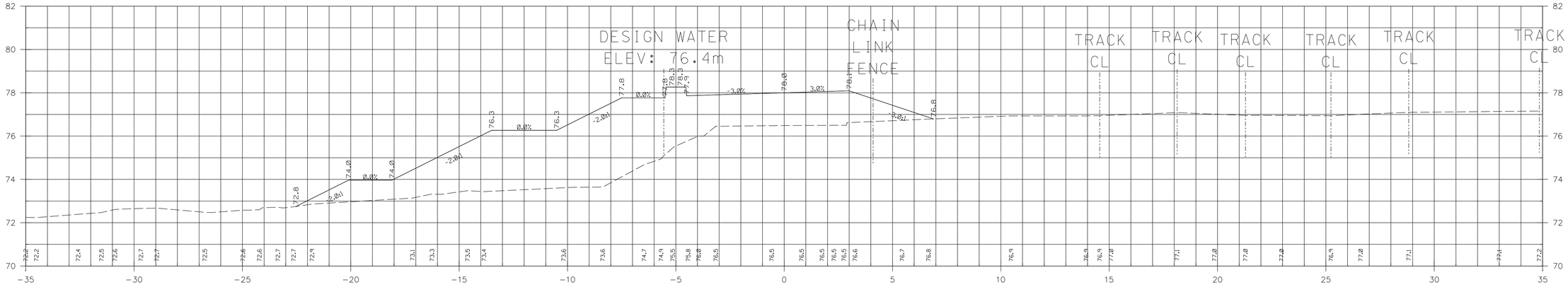
SCALE: 1:100 STA 1+800.00 TO STA 1+840.00



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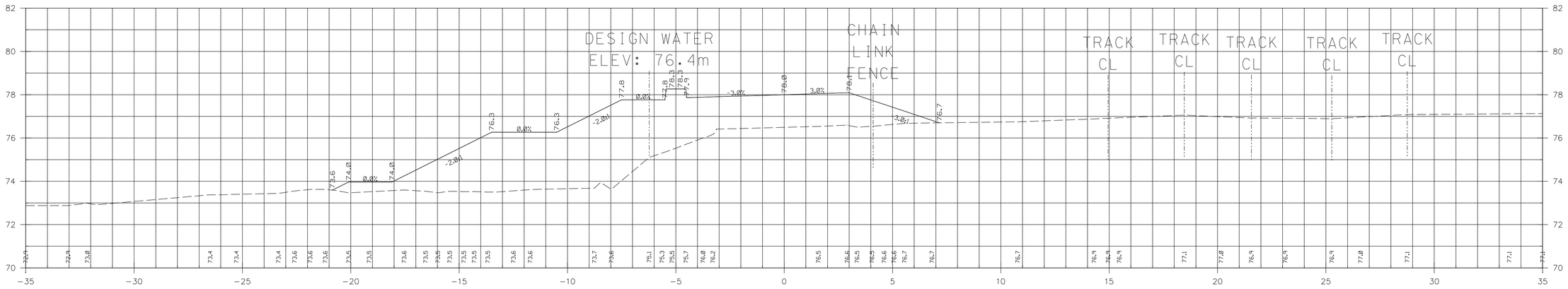
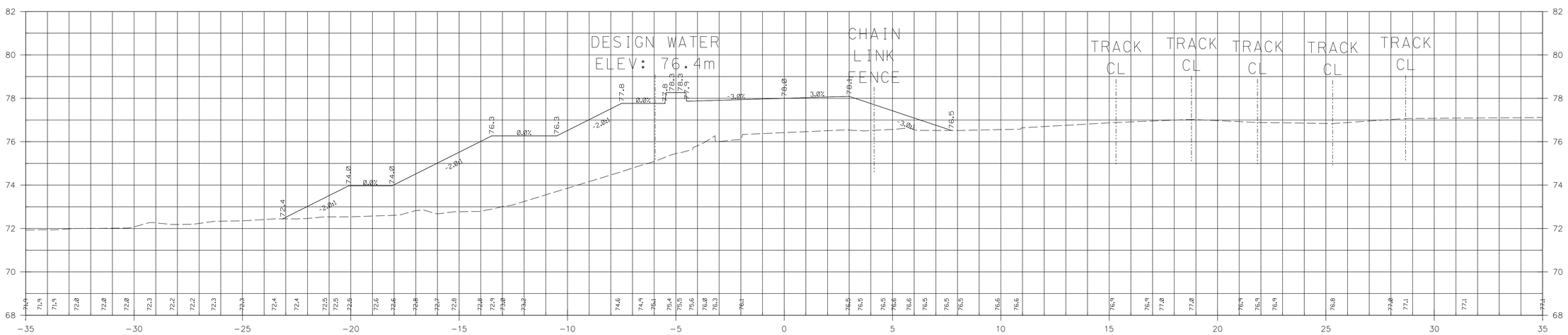


1+820.00



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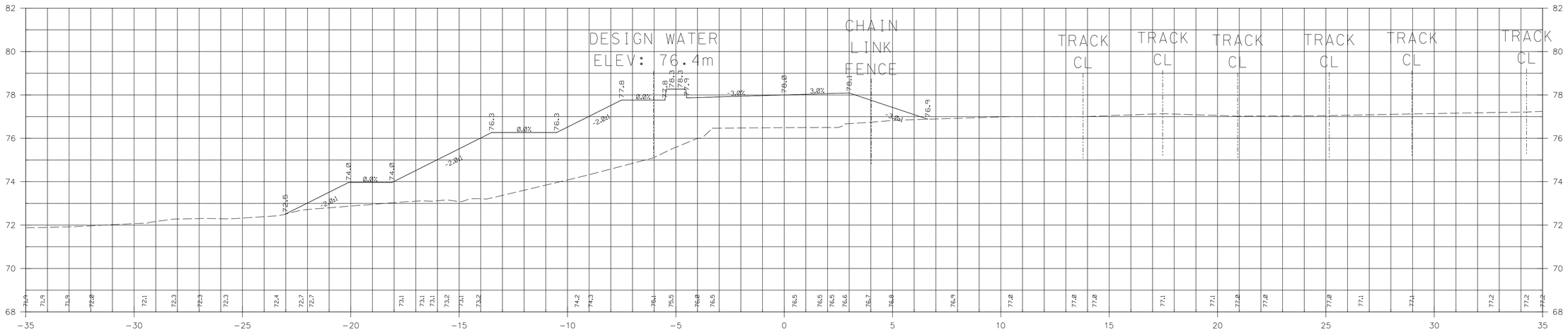
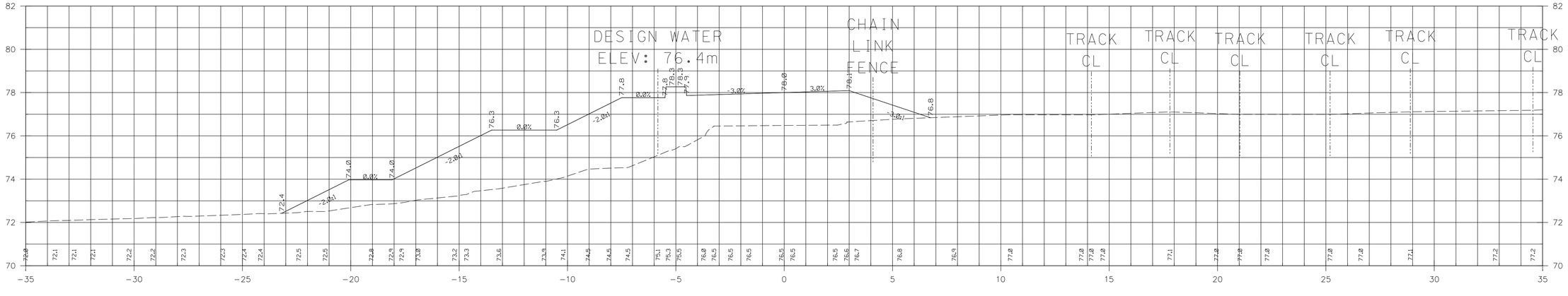


1+880.00



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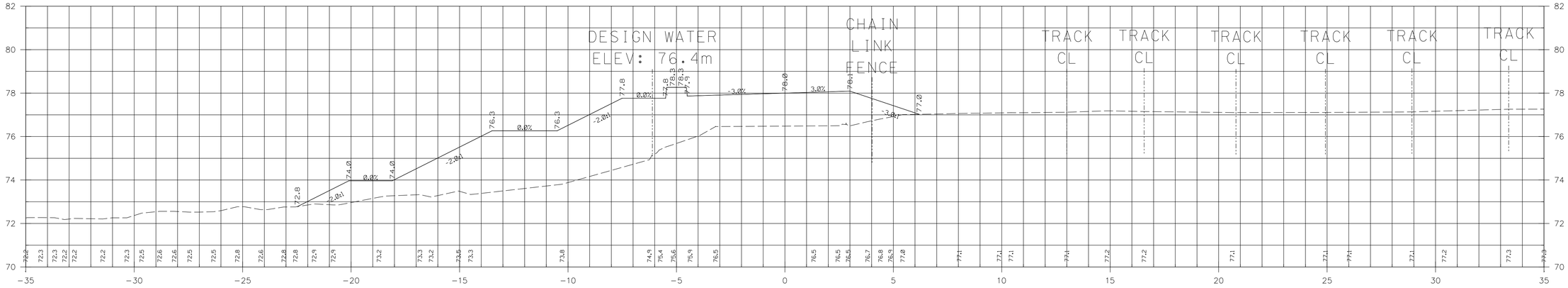

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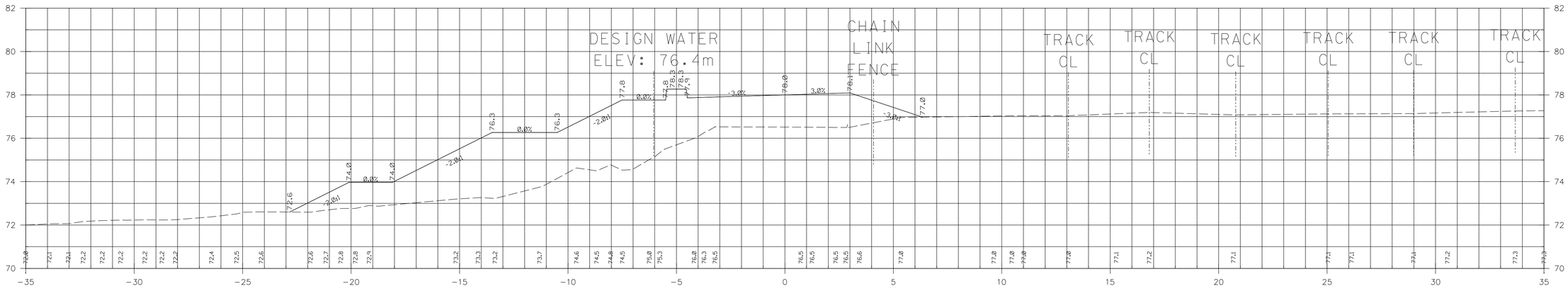

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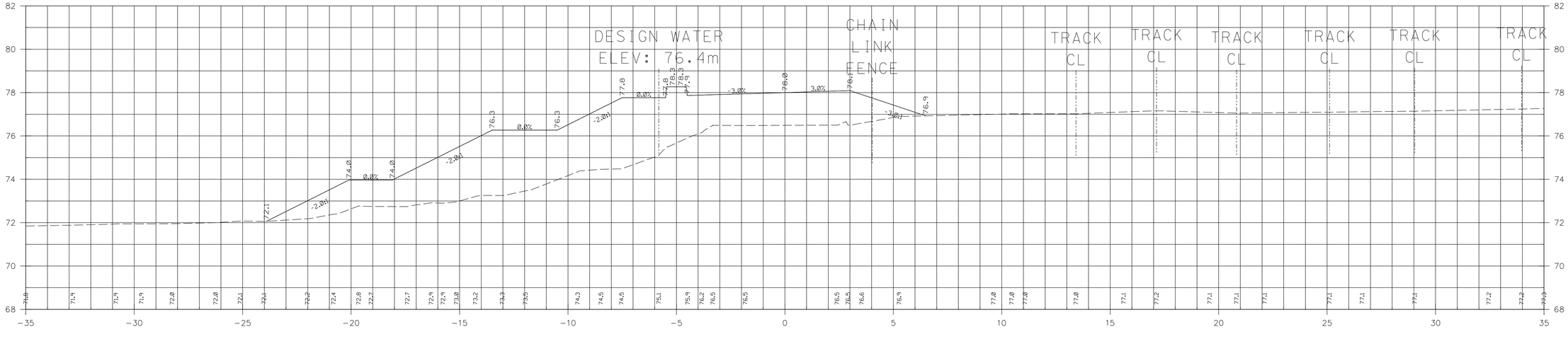
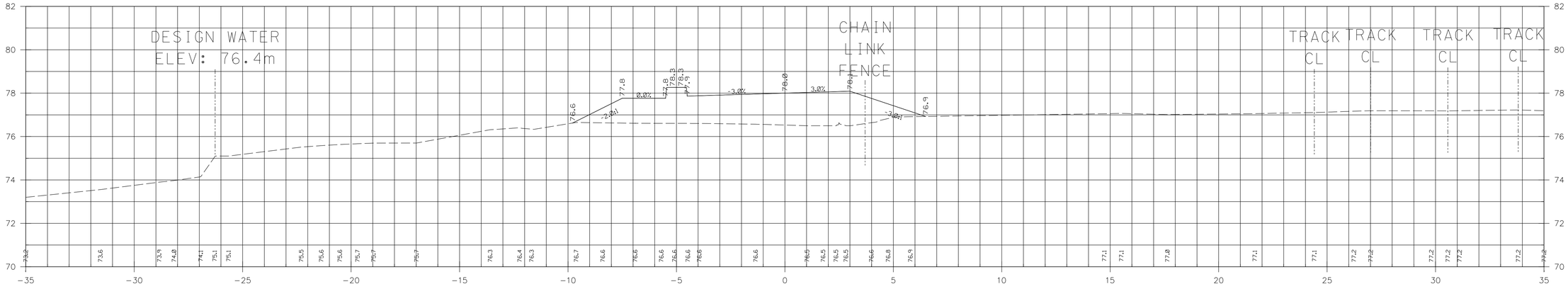


1+900.00

SCALE: 1:100 STA 1+960.00 TO STA 2+000.00



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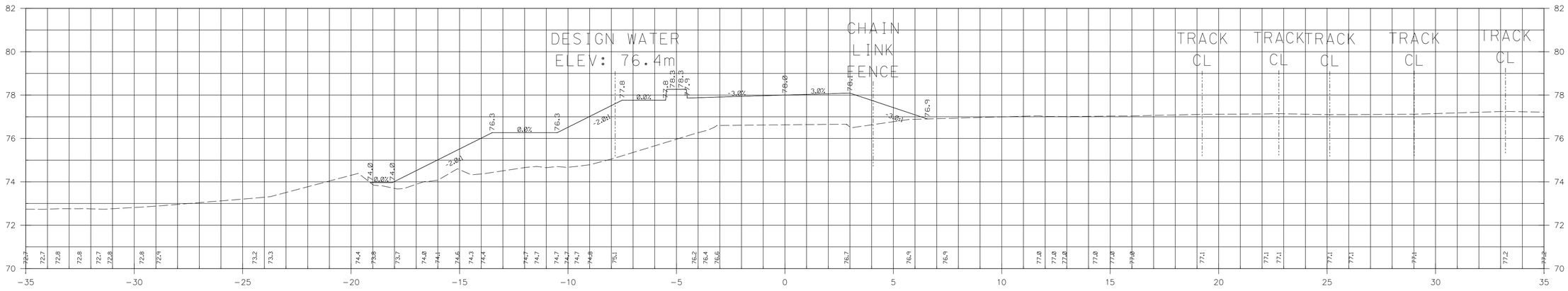

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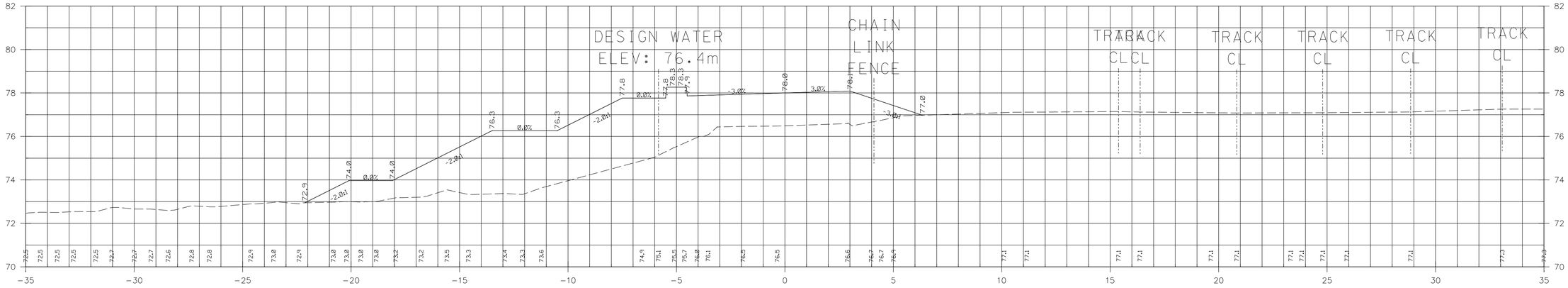
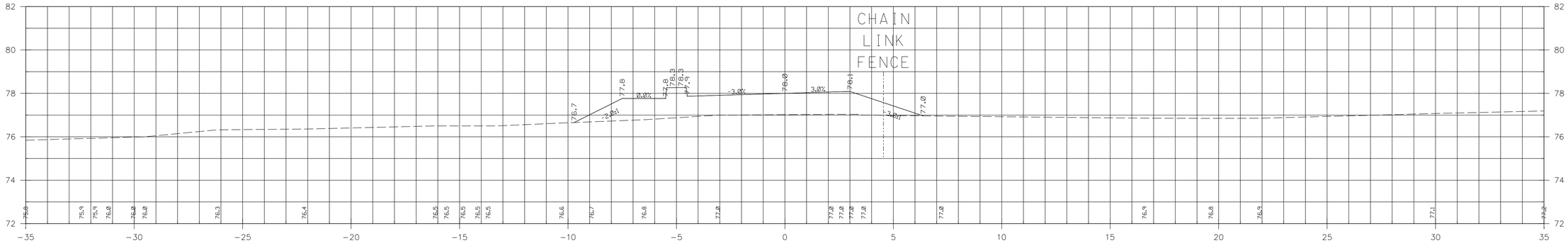


1+960.00

SCALE: 1:100 STA 2+020.00 TO STA 2+060.00



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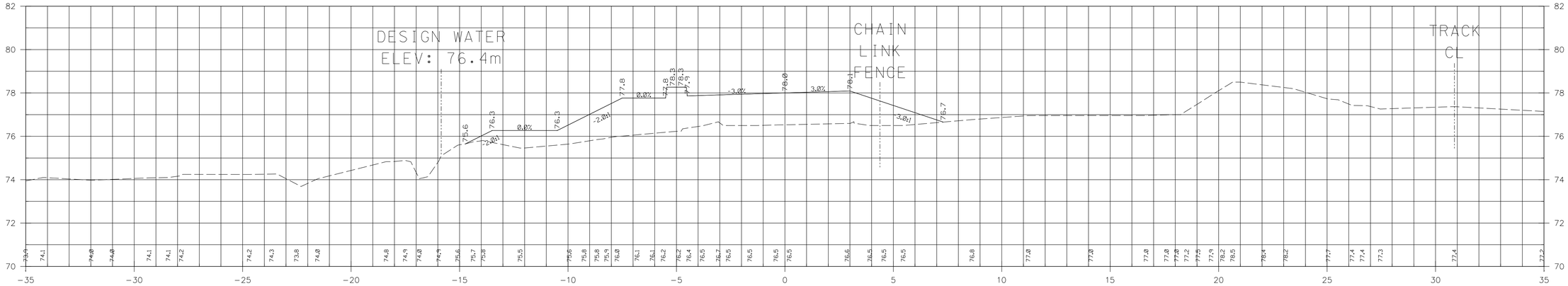
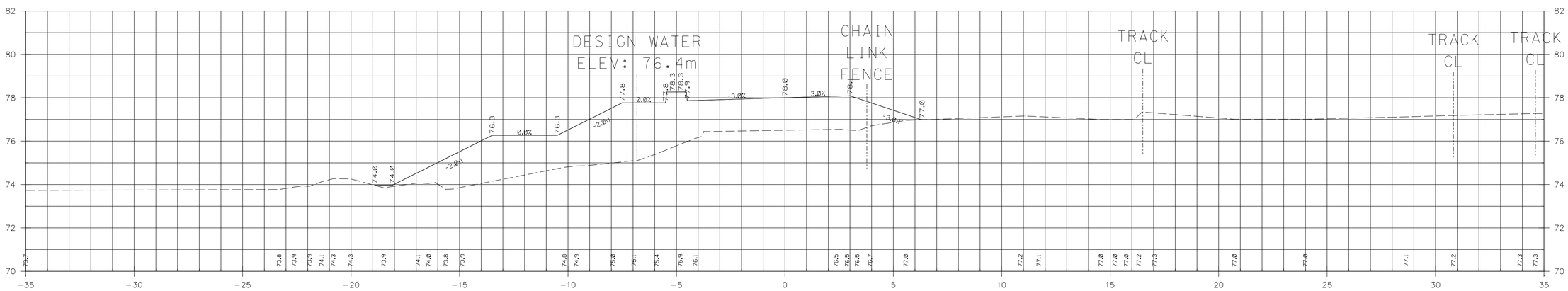
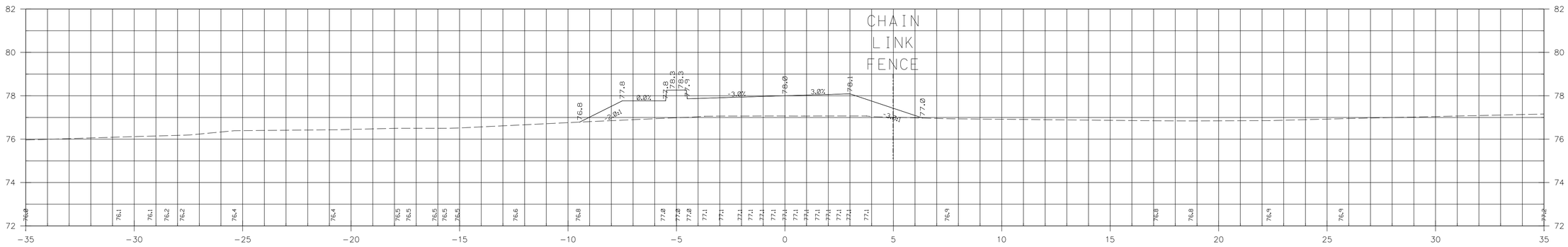


2+040.00

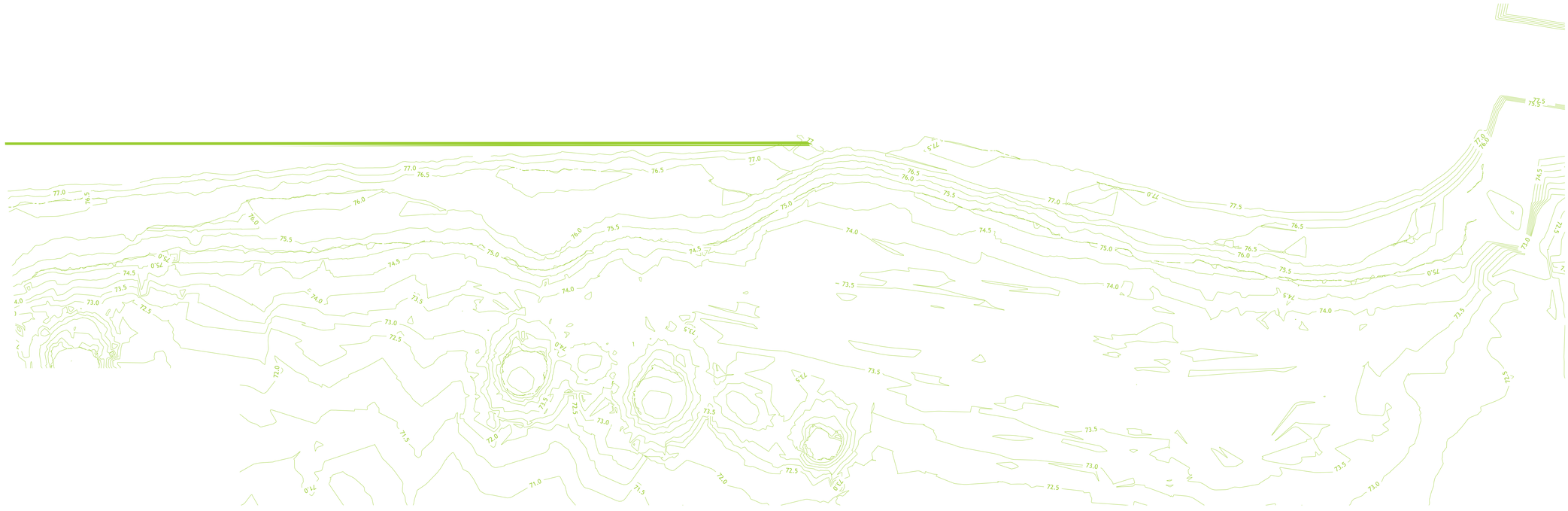


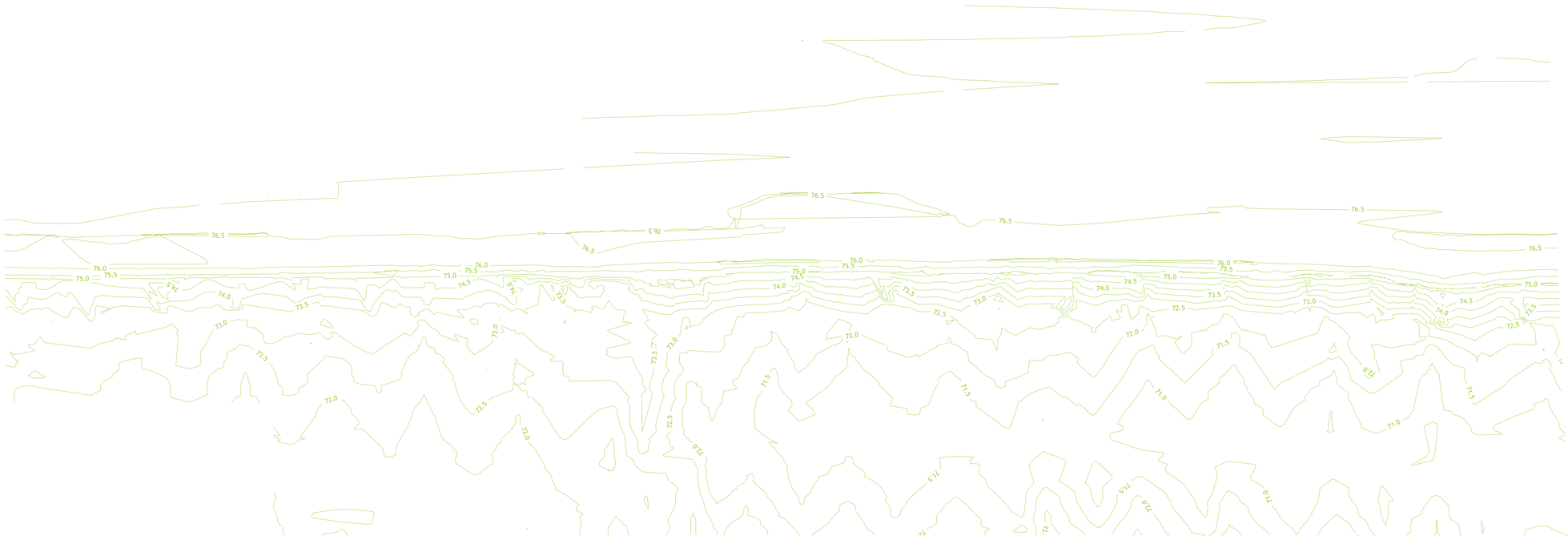
2+020.00

SCALE: 1:100 STA 2+062.16 TO STA 2+062.16



2+062.16




76.5
76.0
75.5
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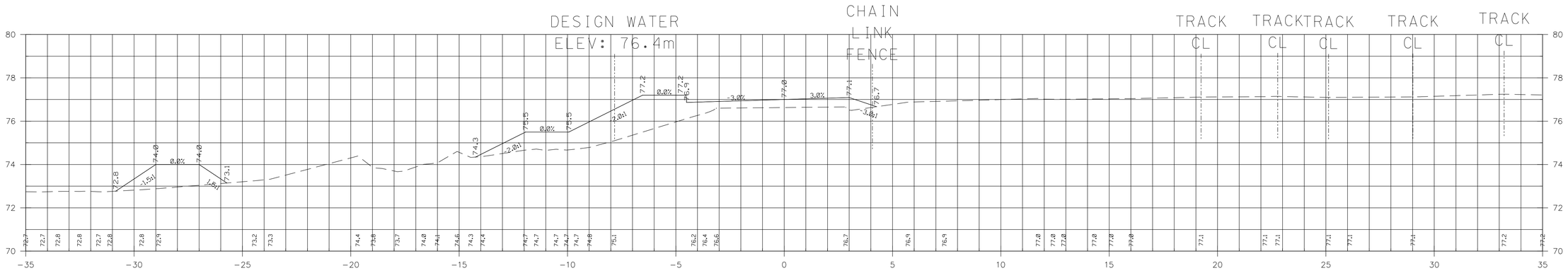
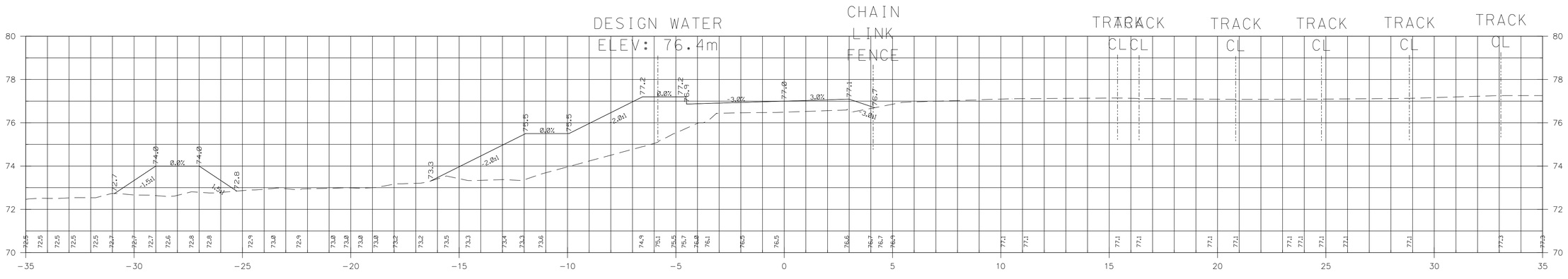
71.5
71.0

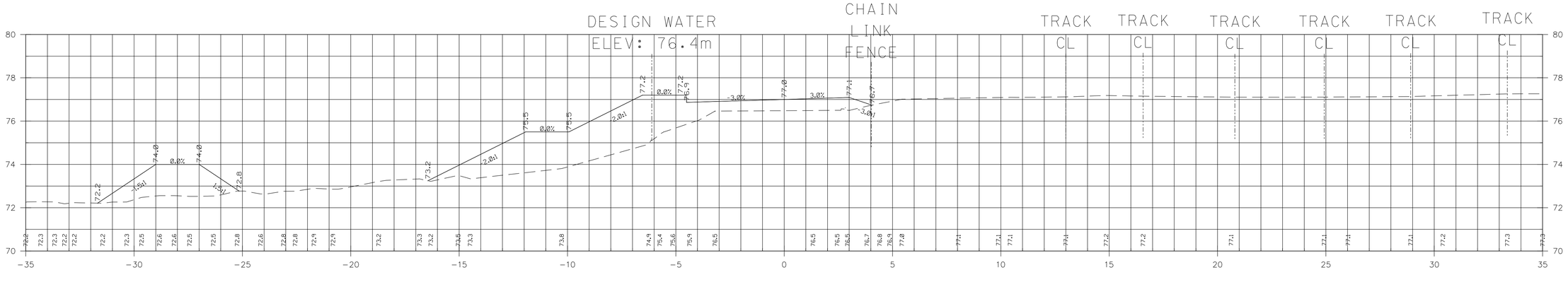
SCALE: 1:100 STA 1+940.00 TO STA 1+980.00



1+980.00

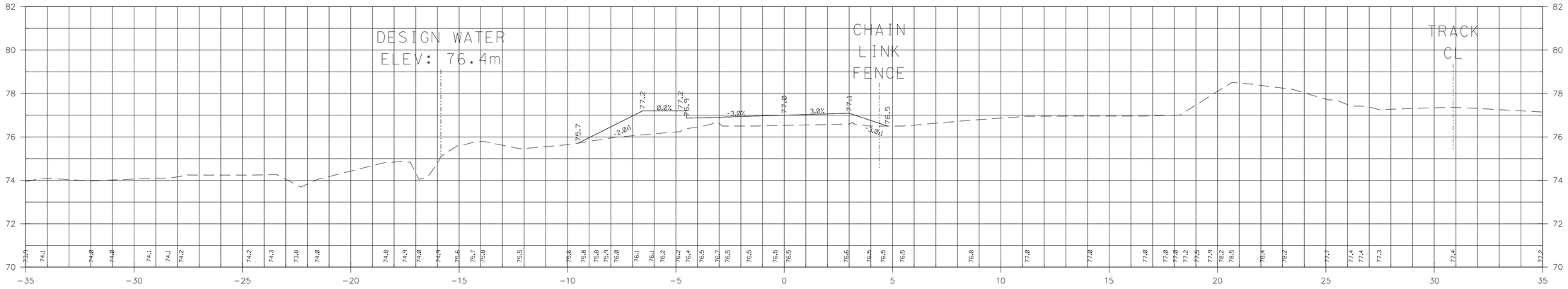


1+960.00

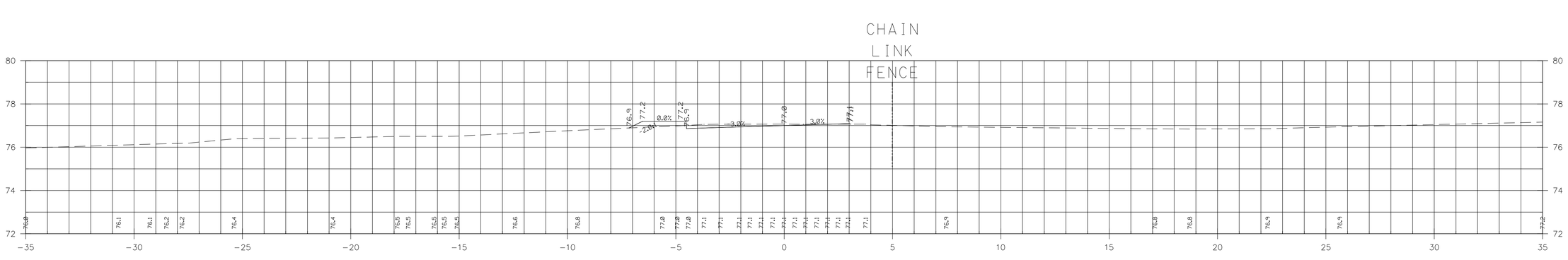


1+940.00

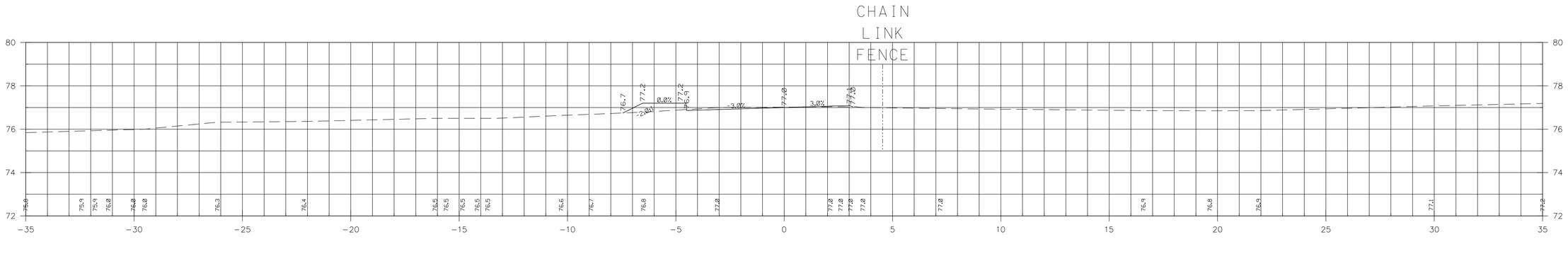
SCALE: 1:100 STA 2+000.00 TO STA 2+040.00



SCALE: 1:100 STA 2+060.00 TO STA 2+062.16



2+062.16



2+060.00

Appendix B

Option 1 – Concrete Retaining Wall Plan and Section
Option 2 – Concrete Toe Wall Plan and Section

FOR AERIAL IMAGERY
TURN ON ORTHO LAYER.

XREFS MUST REFERENCE
THE ORTHO TIFF FILE(s).