Phuentsholing Township Development Project

Technical Due Diligence

Part A: River embankments, land development, cross drainage and stormwater

Part B: Urban Planning and Design

Part C: Common Urban Infrastructure

Part A

River Embankments, Land Reclamation, Cross Drainage, and Stormwater

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Abbreviations

ADB	-	Asian Development Bank
CDCL	-	Construction Development Corporation Ltd.
DHI	-	Druk Holdings and Investment Ltd.
EA	-	Executing Agency
EIA	-	environmental impact assessment
IA	-	Implementing Agency
ICB	-	international competitive bidding
IDPR	-	Integrated Detailed Project Report
MOF	-	Ministry of Finance
NCB	-	national competitive bidding
NECS	-	National Environment Commission Secretariat
PIC	-	Project Implementation Consultant
PTDP	-	Phuentsholing Township Development Project
STP	-	Sewage Treatment Plant
TA	-	technical assistance
TOR	-	Terms of Reference

NOTE

In this report, "$" refers to United States dollars.

Technical Due Diligence: Part A

River Embankments, Land Development, Cross Drainage and Stormwater

I. Introduction

1. This report records key findings of the technical due diligence related to the river embankments, land development, cross drainage and stormwater components of the project.

2. The purpose of the technical due diligence review was to confirm that planning, engineering, and implementation details of the proposed project were done in accordance with established professional principles, practices and criteria, to allow final project evaluation and preparation of ADB project documents to proceed.

3. The review focused on the following main items:

- CDCL's 'Stage 3: Integrated Detailed Project Report (IDPR) – 2nd Draft on 12 August 2016. The IDPR included technical investigations, engineering designs (river training and common infrastructure), drawings and cost estimates, amongst other things.
- HCP submitted their 'Civil Works Package: ZA-1 (Zone A)' – Revision 3 on 31 December 2016. The package included Volume I Drawings, Volume II Technical Specifications, Volume III Bill of Quantities (BOQ), and supporting information for the BOQ.

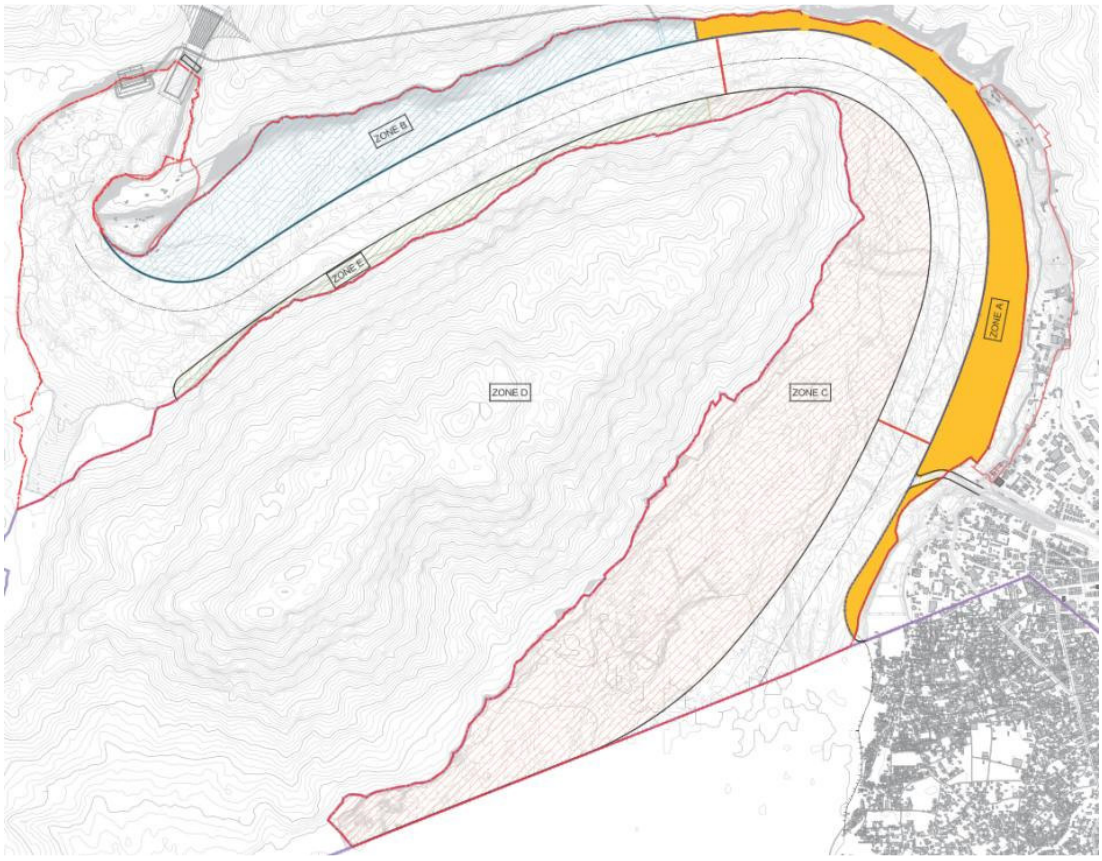
4. Technical due diligence has been undertaken based on these two key outputs, observations made during the site visits undertaken in September 2016 and January 2017, and discussions and correspondence with CDCL.

A. Development Phasing

5. The proposed land development areas were divided into five zones for the Master Plan (Figure 1) comprising: Zone A which will have 66 Ha (Figure 2); Zone B with 94 Ha; Zone C with 277 Ha; and Zone E with 27 Ha, making a total of 464 Ha.

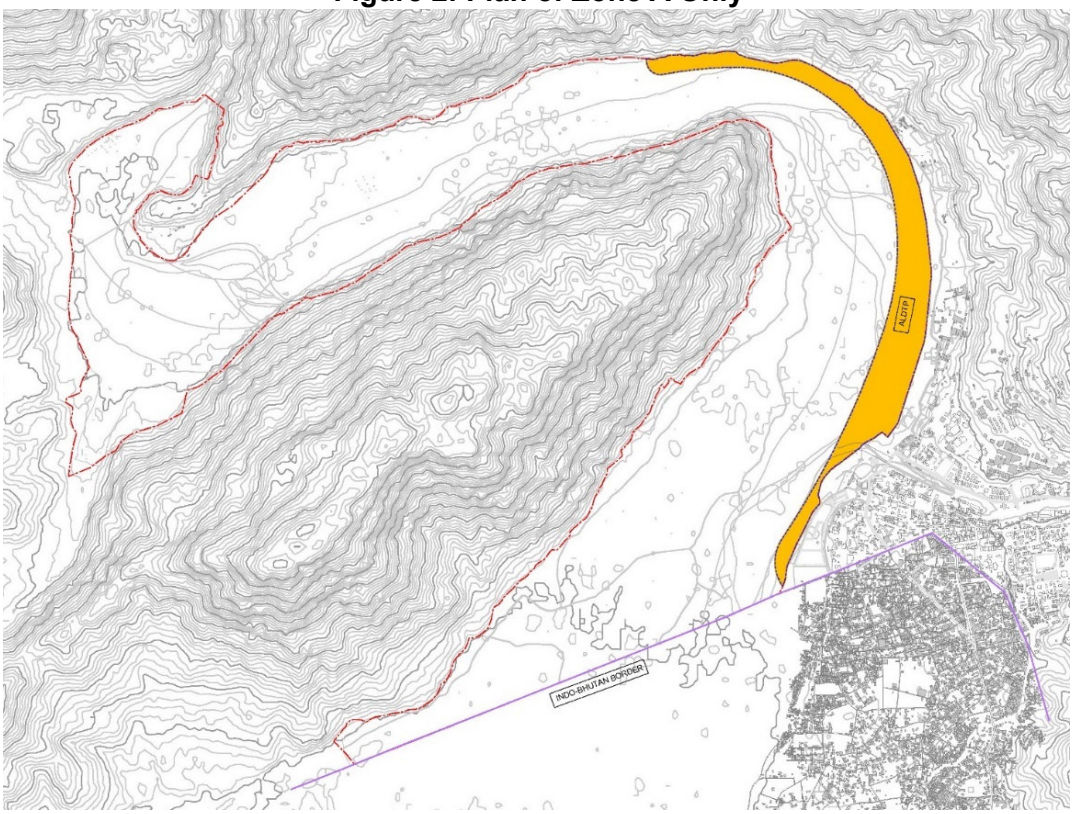
6. The schedule for the Master Plan is for completion of all zones by 2035. The Phuentsholing Township Development Project (PTDP) will develop Zone A while the remaining zones will be developed in subsequent phases, subject to confirmation of demand and financing. Zone A is scheduled for 2017-2022.

Figure 1: Plan of Entire PTDP Development (all zones)



Source: CDCL drawing BM-PB-01, 9/12/16

Figure 2: Plan of Zone A Only



II. Design

A. Review Process

7. Review of the 2nd Draft IDPR was undertaken in September 2016. PPTA comments and recommendations were made in table format to CDCL for review and appropriate action. CDCL reviewed the PPTA comment tables and provided responses to the PPTA. The process was repeated several times, endeavouring to close comments with each round.

8. The IDPR was reviewed to determine, amongst other things, if the investigations, analyses and design are adequate for use as a basis for preparation of drawings, specifications and a BOQ suitable for use in ADB standard bidding documents. All aspects of the IDPR were examined including:

- range of options considered, their engineering and technical viability;
- rationales for the proposed design, specific components, and operational modes;
- assessments of capital costs, and the achievable cost savings; and
- timescale for project implementation.

9. The review considers two scenarios: (i) Zone A only; and (ii) entire development. The following sections summarise the review findings.

B. Key Findings

1. River Hydrology

10. *Catchment.* The Amochhu river system has its origin in China and flows through the western Bhutan districts of Ha and Samtse before finally draining via Chhukha district onto the

plains of India. The upper catchment is at a high elevation with steep slopes. Its source is Mount Pauhunri (7,128 metres (m) above mean sea level [AMSL]) on the border with India and China. Phuentsholing is at a relatively low altitude of 220 m AMSL with a catchment area of approximately 3,785 square kilometres (km^2).[1] The catchment area down to Hasimara gauging station in India, 15 kilometres (km) downstream of the Indo-Bhutan border, is 4,006 km^2. Figure 3 shows the catchment area and locations of interest. Figure 4 shows the location of Phuentsholing, in an oblique aerial image looking north-east (upstream). The confluence of the Amochhu and Omchhu is shown, as is Jaigaon, the city to the south, in India.

11. *Flood history.* Historical flood information for Phuentsholing is scarce[2] and neither Phuentsholing *Thromde* (municipality) nor CDCL have been able to provide information regarding Amochhu floods prior to 2015.[3] The flood information usually available, such as the maximum observed water level (e.g. flood wrack marks) or anecdotal reports of damage sustained in riparian areas, is evidently unavailable, even for the relatively recent 1996 flood which is understood to be the maximum recorded flood at Hasimara. Hydrological data paucity is not unusual but it is unusual to not have the flood damage in recent times documented. Thus, benefits that may accrue to the project due to flood protection of the existing town cannot be assessed or quantified with any certainty.

12. *Flood data*. Observed flood discharge data in the catchment upstream of Phuentsholing is limited to the short record at Doyagang Bridge[4] (2006-present)[5] and the short record at Dorokha[6] (2003-2008).[7] The stage-discharge ratings at both sites are subject to significant uncertainty, particularly for high stages, restricting the utility of any published flood values. Observed flood stage and discharge data at Hasimara has been recorded since 1978, potentially yielding an annual maxima flood series of 37 years. Access to the Hasimara data is prohibited to all but persons 'authorised' by India's Central Water Commission (CWC). Authorised persons are restricted from publishing the data, or otherwise making the data provided to them available to others. CDCL's consultants are understood to have the data but have not been able to include it in the IDPR for these reasons.

13. *Maximum observed flood.* The maximum observed flood at Hasimara is reported to be 5,397 m^3/s on 13 July 1996. The reported flood magnitude remains unsubstantiated as the data has not been made available for verification. It is unclear whether it is an estimate of the instantaneous maximum discharge or the mean discharge for the day in question. It is unclear how it was estimated (e.g. by extrapolation of a stage-discharge rating curve, or by back-calculation using the slope-area method based on observed flood wrack marks at the water level recording station). These aspects are important for verifying the maximum observed value, as well as for derivation of the annual maxima series if it were available.

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[1] Estimates vary from 3,700-3,900km^2. This value is from DHI India, *Toorsa River Flood Mitigation Project – Detailed Feasibility Study and Engineering Design – Data Collection Report*, prepared by DHI Water & Environment (DHI India), January 2007.

[2] The focus is on fluvial flooding derived from rainfall and/or snowmelt. Glacial Lake Outburst Floods (GLOF) are not a feature due to the lack of glacier lakes in the catchment. There is no evidence of landslide dam-break flooding.

[3] The 2015 event was documented by DHI Infra.

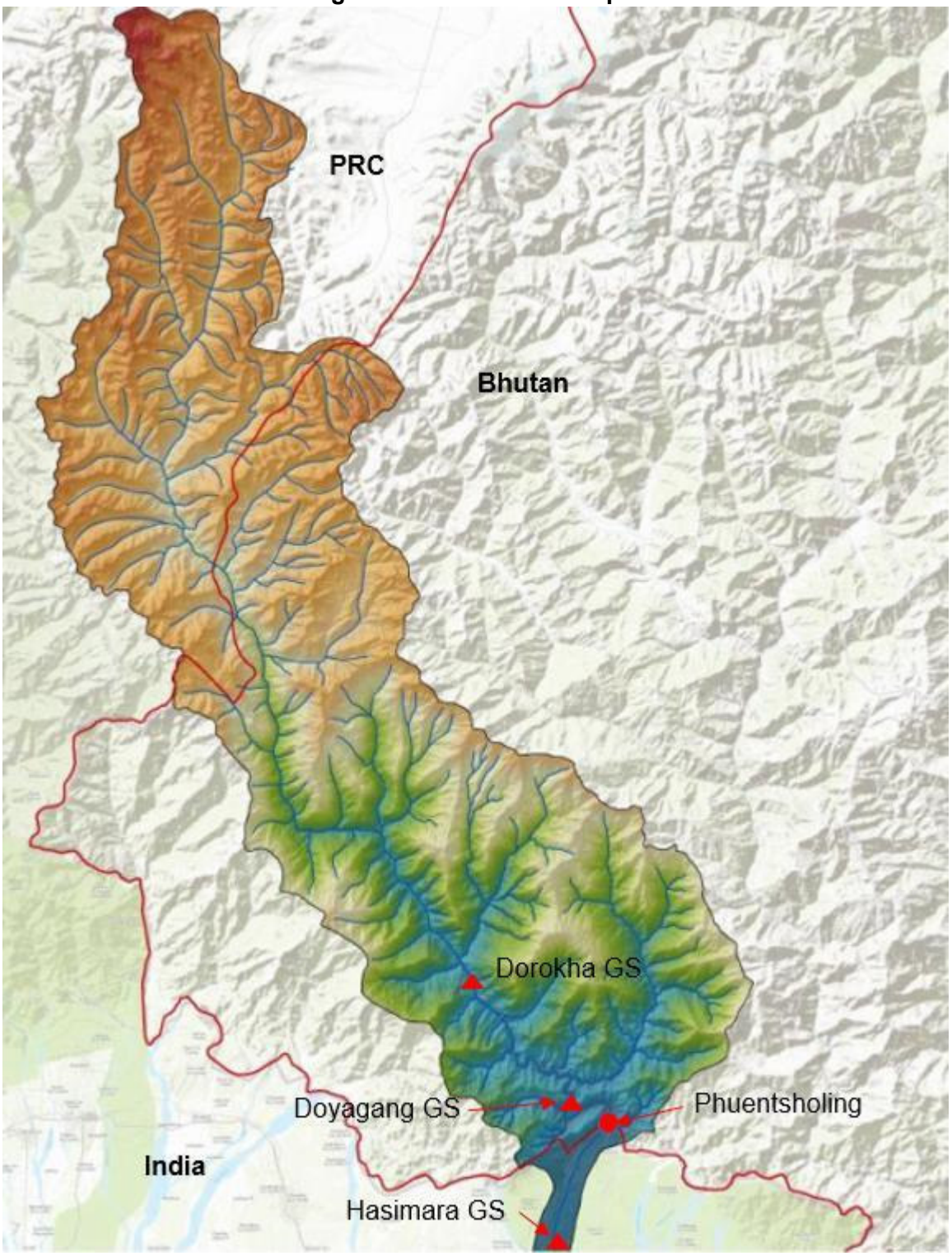
[4] Located just upstream of the town at the exit to the gorge. Twice daily stage readings are available. The catchment area is ~ 3,650 km^2 but has been reported elsewhere as 3,714 km^2.

[5] As advised by the Department of Hydromet Services. Other reports indicate it is available from 2004.

[6] Located further upstream. Daily stage readings are available. The catchment area is ~ 3,055 km^2 but has been reported elsewhere as 3,155 km^2.

[7] As advised by the Department of Hydromet Services. Other reports indicate it is available from 1996.

Figure 3: Catchment area plan



Source: CDCL, Stage 3: Integrated Detailed Project Report (IDPR) – 2nd Draft, 12 August 2016. Annex 4. Fig 2.1. Annotated by PPTA.

Figure 4: 3D Google image of PTDP site and Omchhu confluence

Source: CDCL, Stage 3: Integrated Detailed Project Report (IDPR) – 2nd Draft, 12 August 2016. Main report. Fig 2.53.

14. *Amochhu flood estimates.* Two widely accepted methods have been used to derive flood estimates for the Amochhu at Phuentsholing; flood frequency analysis using the Hasimara data, and synthetic unit hydrograph analysis[8]. The synthetic unit hydrograph estimates were slightly larger so were adopted in preference to the flood frequency estimates. The flood frequency analysis served as a useful check on the synthetic unit hydrograph analysis. The estimated flood values are 5,900 m^3/s and 7,100 m^3/s for the 1 in 50 and 1 in 100 Annual Exceedance Probabilities (AEP) events respectively. These estimates exclude a climate change allowance and are understood to be maximum instantaneous values applicable at Phuentsholing.[9]

15. *Climate change.* Climate change considerations are not included in the flood estimates for the Amochhu. The Climate Risk and Vulnerability Assessment has assessed the impact of climate change on flood flows.[10] This includes applying an appropriate climate change factor to the 1 in 100 design flood and assessing its impact on design freeboard. For example, the 1 in 100 AEP Amochhu flood is estimated to be 7,100 m^3/s, excluding climate change. The estimate would be multiplied by 1.15 to arrive at a revised estimate of 8,165 m^3/s, allowing for climate change. The sensitivity of the project to climate change, with all zones developed, has been assessed in terms of the estimated peak flood discharge and resulting peak water surface level for the design event (1 in 100 AEP) with and without application of the climate change factor. In summary, inclusion of a climate change allowance reduces the freeboard by 0.33 m, leaving a freeboard of 0.67 m above the estimated water level for the design event. However, it is not recommended to add the climate change allowance to the design flood and maintain the 1 m of freeboard as that would be unduly conservative.

[8] Central Water Commission. 1991. *Flood Estimation Report for North Brahmaputra Basin (Sub-Zone 2a),* Delhi.
[9] It is unconfirmed whether the estimates were derived at-site or at Hasimara. As the catchment area difference is relatively small, and it is conservative to adopt the estimates at Hasimara, it is acceptable to consider the estimates to be applicable at Phuentsholing without adjustment.
[10] See the Climate Risk and Vulnerability Assessment (available from the list of linked documents in Appendix 2).

16. *Design flood selection.* The 1 in 100 AEP flood, excluding a climate change allowance, has been selected as the design flood for flood defence purposes. In the absence of country specific standards or guidelines, the selected flood protection standard would usually be based on economic and financial analysis of the ultimate development such that the incremental benefits of increasing protection can be demonstrated and justified against the incremental cost of providing it. In this case, it appears reasonable to adopt a flood protection standard of 1 in 100 (excluding climate change). Aspects considered when seeking justification include, by inspection:

- the scale of the investment
- the perception by future leaseholders and their insurers
- the level of uncertainty inherent in flood estimates
- the level of uncertainty inherent in hydraulic and sediment modelling in this type of environment
- the minimum freeboard allowance of 1 m
- the alignment with Indian standards and overseas practice
- the need to account for climate change to satisfy ADB requirements (and possibly others)
- the proposed use of a flood early warning system (FEWS) and development of a flood management plan (FMP) which will include evacuation procedures.

2. River Hydraulics

17. *1D Hydraulic modelling*. A one dimensional (1D) hydraulic model was used in steady state and unsteady mode, with a 'fixed-bed', for design purposes to assess water surface elevations and velocities for the pre-and post-development cases (natural vs trained). The 1D model was run for two post-development scenarios: (i) Zone A only; and (ii) entire development.

18. *1D Model domain.* The 1D model domain extends from Doyagang Bridge to the India-Bhutan border. Ideally it should extend as far downstream as required until the impacts of the project are no longer influencing present conditions. Towards this end, CDCL obtained the 2006 survey[11] (70 cross sections) from Doyagang bridge to Hasimara and undertook a comparison of the 2006 survey with the survey used within the project area for the 1D modelling undertaken to date. Unfortunately, it was found that there were irreconcilable datum differences, restricting the use of the data.

19. *Scour estimate.* Lacey's formula has been used to determine scour depth based on the hydraulic results of the 1D model.

20. *Sensitivity testing.* The 1D hydraulic model is uncalibrated,[12] although sensitivity testing of the Manning's n values has been undertaken.

21. *2D Hydraulic modelling*. A two-dimensional (2D) depth-averaged model is recommended for detailed design of the ultimate development to characterise the flow concentration/velocity field across the river, throughout the domain, and on the large sweeping bend. In addition, it is recommended the 2D model have a 'mobile-bed' with sediment transport capability. The model should be used to confirm the estimated water surface elevations,[13] velocities, channel morphology and scour for a range of AEP, and for the pre- and post-development cases.

[11] It is the same survey used by DHI India in their 2007 and 2013 reports.
[12] The model is uncalibrated in the reach of interest for the natural condition. Calibration would require observed water levels for a given discharge in the reach of interest.
[13] Including super-elevation and with a robust assessment and sensitivity testing of the assumed Manning's n values, with and without sediment deposition.

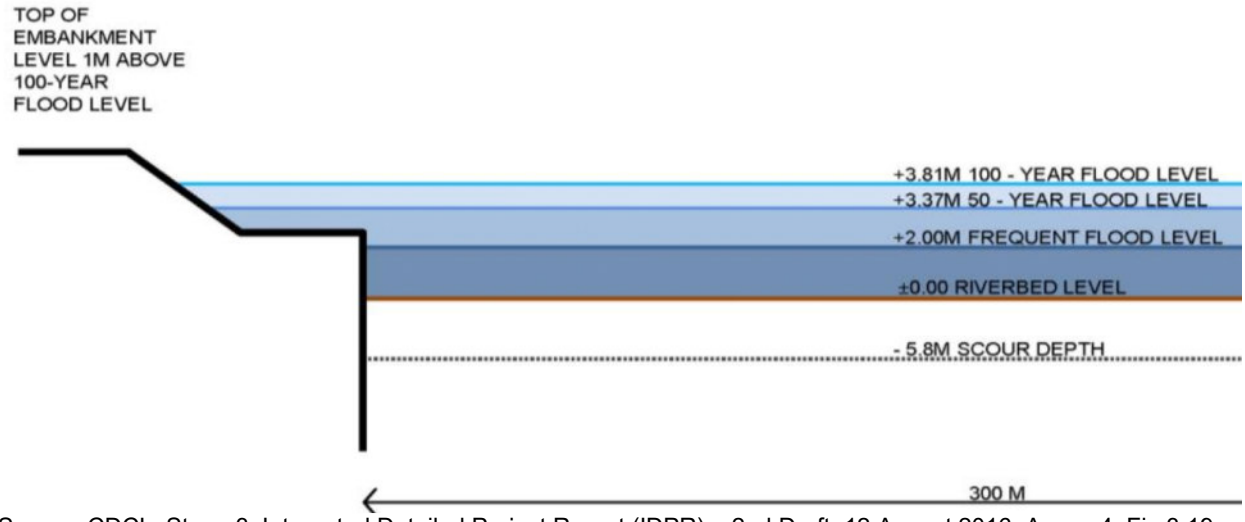
Ultimately the model will improve confidence in the overall designs, and provide a necessary check on the scour estimates that have been undertaken. This is particularly important for design of the diaphragm walls. A 2D modelling scope of work has been provided to CDCL.[14] HCP have prepared a preliminary 2D model for the entire development however it is recommended that further 2D modelling is undertaken based on the above recommendations before finalizing the designs of the remaining zones.

22. *2D Model domain.* Ideally the 2D model should extend as far downstream as required until the impacts of the project are no longer influencing present conditions. To achieve this, new topographic and bathymetric surveys in India will need to be procured. The earliest this could happen would be after the monsoon season in 2017.

a. *Channel Profile*

23. *Base case.* CDCL's proposed prismatic channel is shown in Figure 5 as a schematic, along with key levels initially *proposed* by CDCL, based on the ultimate development (i.e. Zones A to E). Note that the section is symmetrical about the channel centreline.

Figure 5: Channel cross section



Source: CDCL, Stage 3: Integrated Detailed Project Report (IDPR) – 2nd Draft, 12 August 2016. Annex 4. Fig 3.19

24. *Channel roughness (Manning's n).* CDCL initially adopted a value of 0.030 for the existing river through the PTDP reach and 0.028 for the proposed channel.[15] CDCL selected a value of 0.028 based on: a) back calculation of n=0.030 at the Hasimara gauging station for the maximum observed flood (in 1996) and; b) making a small reduction (0.002) to account for the prismatic/uniform nature of the proposed PTDP channel. However, it has been agreed with CDCL to use a slightly more conservative design value of 0.035 with sensitivity tests of 0.028 and 0.042. Final designs have used a value of 0.035 for the main river channel and the finished ground elevations throughout Zone A have been raised an additional 0.5 m from initial designs.

25. *Design flow depths and* freeboard. The estimated normal[16] flow depths with n=0.035 are:

- 4.35 m for the 1 in 100 AEP design flood (7,100 m^3/s)

[14] PPTA, *2D model recommendations*, memorandum from C Dunlop to K Dhakal, 16 February 2017.
[15] IDPR Annex 4, p15, and p21.
[16] 'Normal' is synonymous with 'uniform' in hydraulic terms. It describes the depth under uniform steady state conditions in the absence of any changes in time or space, including backwater effects (i.e. $S_f \sim= S_o$).

- 3.86 m for the 1 in 50 AEP (5,900 m^3/s)
- 2.30 m for the Frequent Flood Level[17] (2,558 m^3/s)

26. *Super-elevation.* The USACE method[18] has been applied to account for water surface super-elevation at the river bend. This shows that an allowance of approximately 0.50 m is required for the 1 in 100 AEP event (i.e. an increase of 0.50m on the outside of the bend and a similar drop on the inside). Hence final designs have explicitly included an additional 0.5m on the outside of the bend in Zone A.

27. *Conclusions.* The final design flood levels and finished fill levels were increased in Zone A as follows:

- The increase due to using Manning's n of 0.035 is 0.50 m and applies throughout the Zone.
- The increase due to super-elevation is 0.50m is applied between Outfall 4 through to Ducted Outfall 4.

28. The maximum increase in finished fill levels is 0.54m + 0.5m = 1.04 m. In practical terms, it is 1 m. The small difference should be ignored for simplicity.

29. For freeboard, the embankments either side of the channel are to be set 1 m above the 1 in 100 AEP water level, plus super elevation and/or bridge afflux where appropriate. The calculations assume a bed gradient of 1 in 200, a Manning's n value of 0.035, and no sediment deposition or other channel cross section changes take place after the prismatic channel is constructed. All flood discharges exclude a climate change allowance.

3. Sediment and River Morphology

30. *Sediment transport and river morphology*. Sediment transport changes for the Zone A only scenario will be insignificant. For the entire development scenario, more detailed sediment transport and river morphology will be investigated with use of a 2D model. Earlier reports[19] by DHI India (2007 and 2013)[20] include discussion on these matters. The content in those reports related to the pre-development case is still valid. The discussion regarding the post-development case (entire development scenario) needs to be read acknowledging that the layout of the river training scheme proposed at the time is different from that currently proposed. The earlier DHI India reports serve as a guide.

31. *Baseline.* It is recommended that the river reach downstream of the India border is surveyed to provide a baseline for comparison with any post-development river morphology changes. This particularly applies for the entire development of all five zones which will channelize the river. Due to access restrictions, new topographic and bathymetric survey in India has not been obtained. It is recommended that historic and recent satellite imagery is procured. In addition, a photographic survey of the left bank through Jaigaon should be undertaken early while Zone A is under construction. This could be useful later if complaints arise regarding increased lateral scour.

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[17] Based on Section 2.4.1 of Annex 4, the Frequent Flood Level is understood to be 'the highest flood discharge observed twice in the last 10 years'. This isn't a commonly used term in the industry but it serves the purpose. Note that it is more than the Mean Annual Flood which is the average of the annual series of instantaneous flood peaks over the available record.

[18] USACE, *Hydraulic Design of Flood Control Channels*, US Army Corps of Engineers EM1110-2-1601, 1991

[19] DHI India, *Toorsa River Flood Mitigation Project – Detailed Feasibility Study and Engineering Design*, Draft Final Report, August 2007

[20] DHI India, *Revision of Hydrological & Hydraulic study for Amochhu Land Reclamation & Township Project*, Final Report, December 2013

32. *On-going* maintenance *costs*. Ongoing in-river sediment/ gravel management will be required for both scenarios[21] upstream of the channel, throughout the channel and downstream of the channel. The success of the river training works and flood protection benefits depend upon it. An adequate allowance for the resources required needs to be made in the O&M budget.

4. River Training Works

33. *Training requirement*. River training works are required for the PTDP to achieve several interrelated objectives.

- Divert the river away from the existing left bank areas which are susceptible to lateral erosion and scour
- Realign and confine the river to make room in the floodplain for land reclamation
- Protect the reclaimed land from inundation and erosion
- Protect the training works from excessive scour
- Protect the works from excessive deposition

34. *Erosion problem*. The river needs to be trained, or diverted, away from the existing left bank areas which include the LAP, Omchhu confluence and the Sewage Treatment Plant (adjacent to the India-Bhutan border), regardless of the PTDP. Figure 6 highlights the river reach that is naturally susceptible to lateral erosion and scour as the river turns through the bend. The left bank is presently unprotected from erosion and scour, apart from ad hoc attempts in selected areas using gabions which have proved to be a temporary solution only. The boundary between active river channel and floodplain at higher levels is largely undefined, which is a feature of this type of river.

Figure 6: River reach that is susceptible to lateral erosion

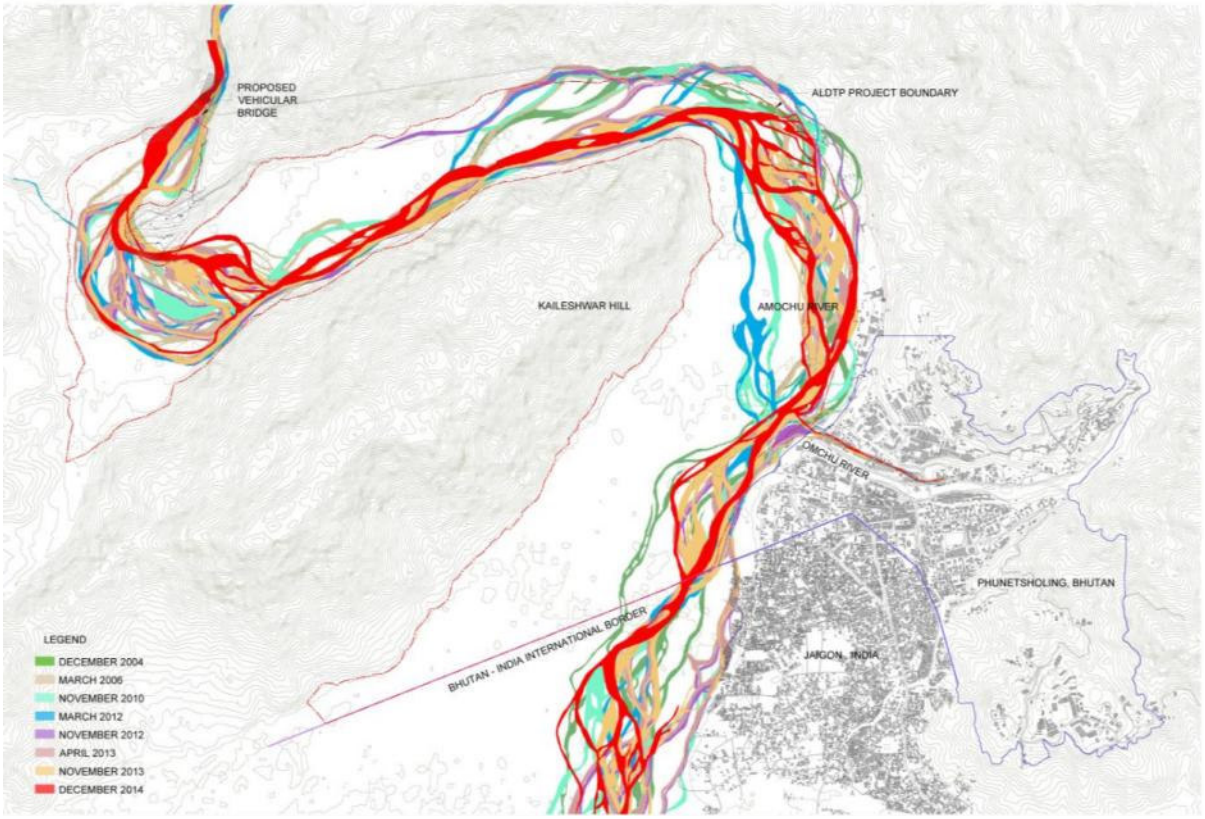
Source: CDCL, Stage 3: Integrated Detailed Project Report (IDPR) – 2nd Draft, 12 August 2016. Annex 4. Fig 0.2

35. *River realignment*. The river requires realignment and confinement to make room in the floodplain for land reclamation. Figure 7 highlights the 'meander belt' which shows the variability of the dry season braid over the period 2004-2014. A similar map showing the river channel during

[21] Scenario (i) Zone A only, and scenario (ii) entire development.

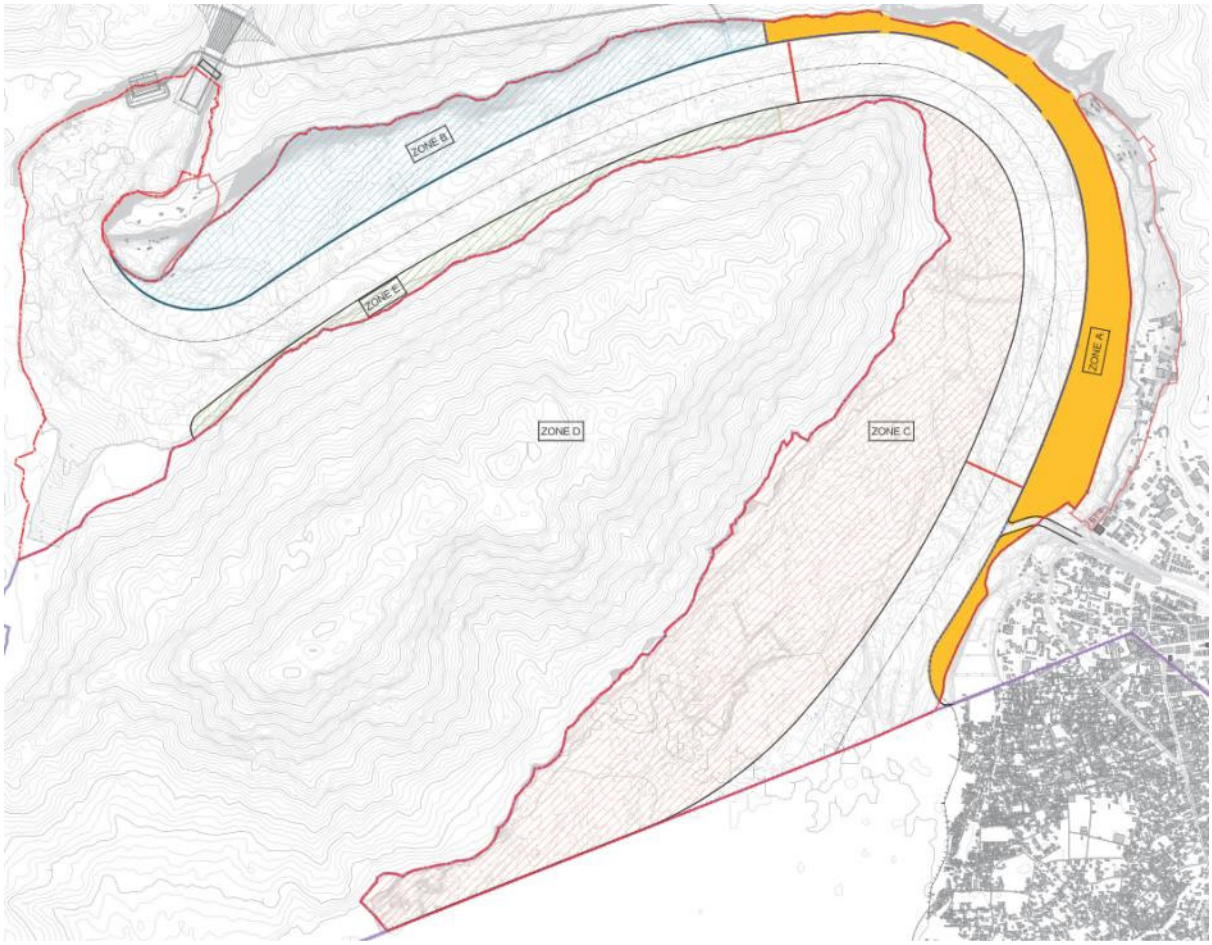
the monsoon would show the discharge spreading across the width of floodplain, encroaching on Phuentsholing. The realignment is determined, amongst other things, by the need to gradually turn the river discharge through the bend without abrupt changes in direction which would exacerbate erosion and scour potential. Figure 8 shows the proposed river realignment for the ultimate development. The alignment geometry in plan view is reasonable, including the use of streamlined transitions at the start and end of the realignment.

Figure 7: Meander belt



Source: CDCL, Stage 3: Integrated Detailed Project Report (IDPR) – 2nd Draft, 12 August 2016. Annex 4. Fig 3.8

Figure 8: Training wall extent and alignment

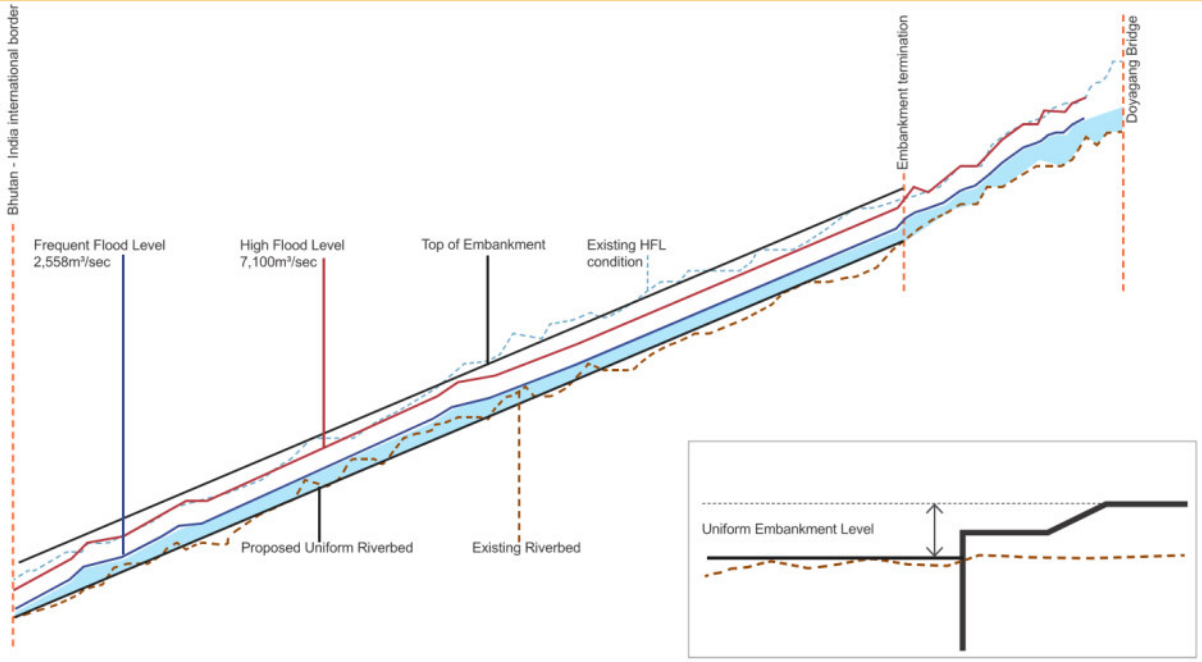


Source: CDCL drawing BM-PB-01, 9/12/16

36. *River confinement*. A balance must be struck between winning developable space and 'squeezing' or overly confining the river. The overall gradient is fixed by levels at each end of the project. The narrower the prismatic channel, the higher the design flood level and velocity will be, and vice versa. The higher the design flood level, the higher the embankments must be. The higher the velocity, the greater the scour depth, increasing the cost of providing river bank and toe protection works. For the ultimate development scenario, CDCL have adopted a base width for the prismatic channel in the ultimate development of 300m, which typically results in an increase in design flood level for a given event. Figure 9 shows a comparison of existing and proposed water levels on a long section through the river. The increases vary depending on location.[22] The proposed channel cross section shape and base width for the ultimate development are appropriate.

[22] These results are indicative only as they are based on the 1D hydraulic model. The 2D model results, when available, will govern the design flood levels and be more representative of the velocity field for the ultimate development.

Figure 9: Long section showing comparison of existing and proposed water levels



Source: CDCL, Stage 3: Integrated Detailed Project Report (IDPR) – 2nd Draft, 12 August 2016. Main report. Fig 4.77

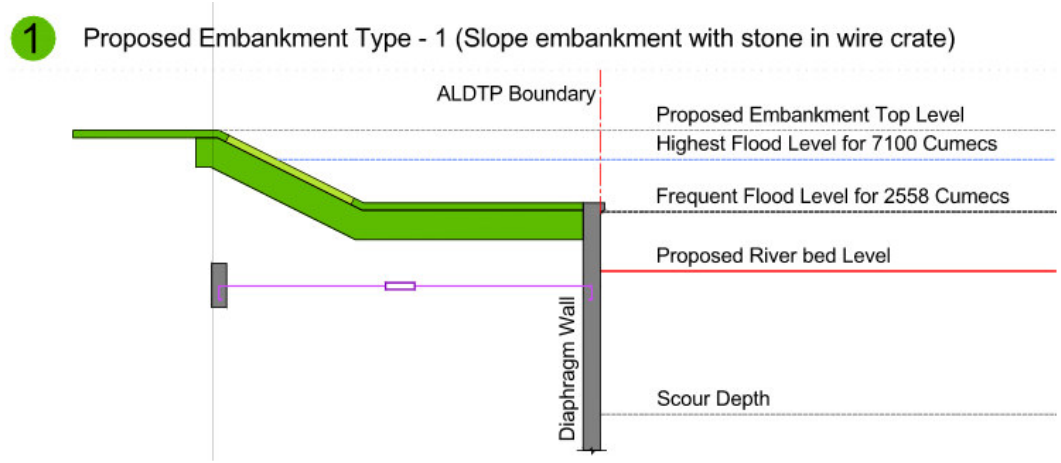
37. *River bank options*. The reclaimed land requires protection from inundation and erosion. There are many options for forming the river banks and protecting them from erosion and scour including:

- Reinforced concrete cantilever retaining walls
- Unreinforced concrete/masonry gravity retaining walls
- Riprap[23] or stone pitching
- Gabions ('stones in wire crates')

38. There are advantages and disadvantages of each option from a cost, durability, hydraulic, land take and aesthetic perspective. CDCL's proposal is to use a combination of 1V:2H sloped embankments and vertical retaining walls to effectively form river banks between an upper and lower promenade, and thus contain and support the engineered fill along the riverside edge of the development. The top of the embankments/ retaining walls will match the finished level of the engineered fill, which will be 1m higher than the design flood level for the 1 in 100 AEP event plus super elevation and/or bridge afflux where appropriate, offering protection from inundation up to the design event. Most the embankments will be protected by stones in wire crates with interlocking precast paving blocks on the surface (Type 1). Reinforced concrete cantilever retaining walls (Type 2) will be used where the velocities are highest, on the outside of the bend in Zone A. A modified embankment detail will be used where the embankment terminates at either end of the training works (Type 3 and 4) in combination with guide banks. Types 1 to 4 are shown in Figures 10, 11, 12 and 13 respectively. Type 4 is protected with stone pitching only. The selected river bank types are appropriate but all embankment types require integration with riverbed/ toe protection.

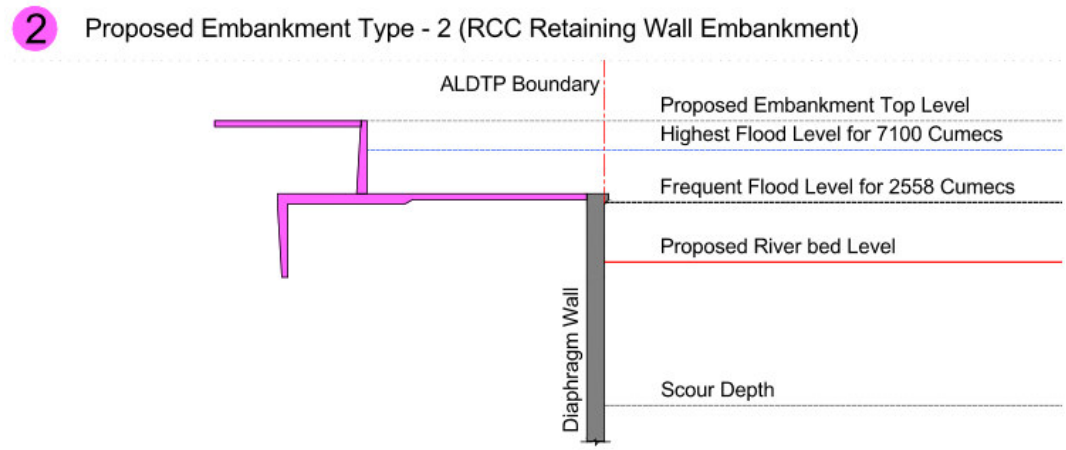
[23] Riprap typically comprises large, graded, angular rock that is dumped/ placed on a graded filter layer or geotextile.

Figure 10: Wall type 1 (deadman anchor and embankment)



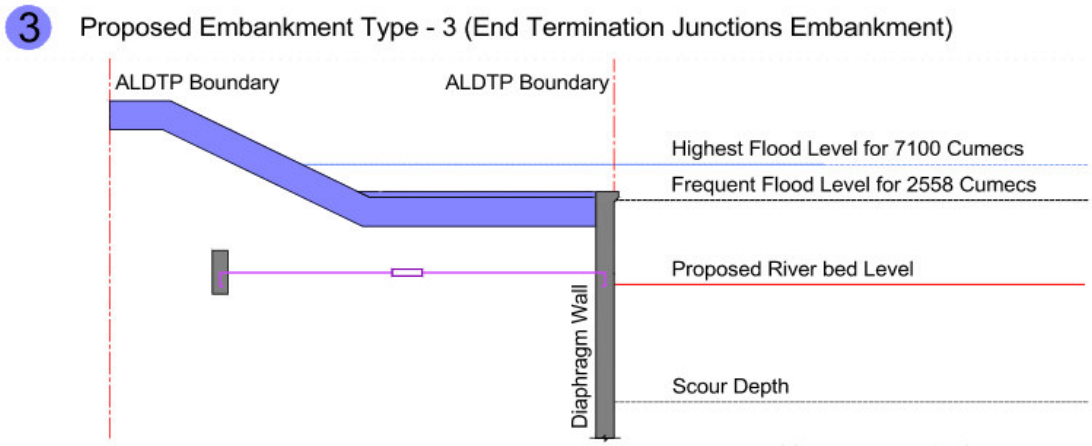
Source: CDCL, Stage 3: Integrated Detailed Project Report (IDPR) – 2nd Draft, 12 August 2016. Main report. Fig 4.96

Figure 11: Wall type 2 (anchor slab and retaining wall)



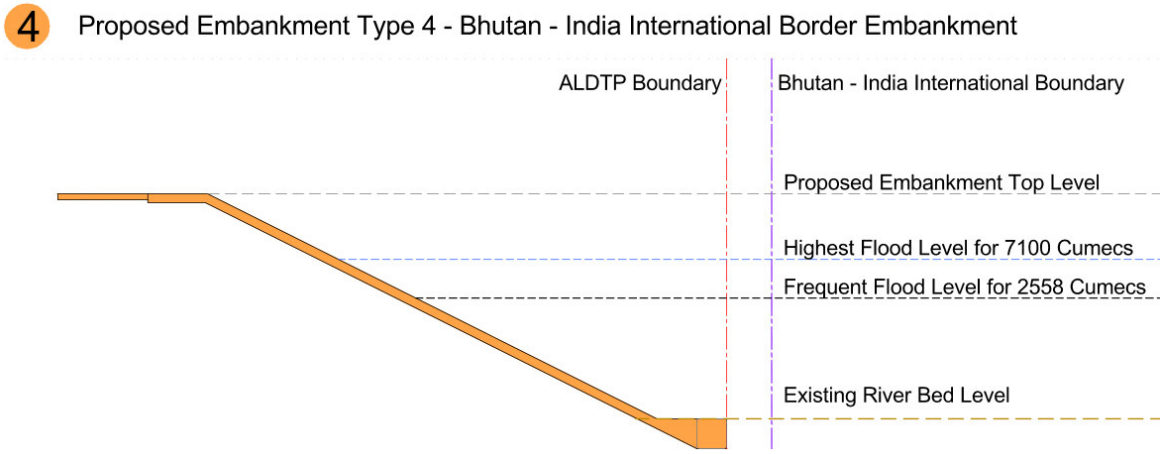
Source: CDCL, Stage 3: Integrated Detailed Project Report (IDPR) – 2nd Draft, 12 August 2016. Main report. Fig 4.94

Figure 12: Wall type 3 (deadman anchor and embankment)



Source: CDCL, Stage 3: Integrated Detailed Project Report (IDPR) – 2nd Draft, 12 August 2016. Main report. Fig 4.97

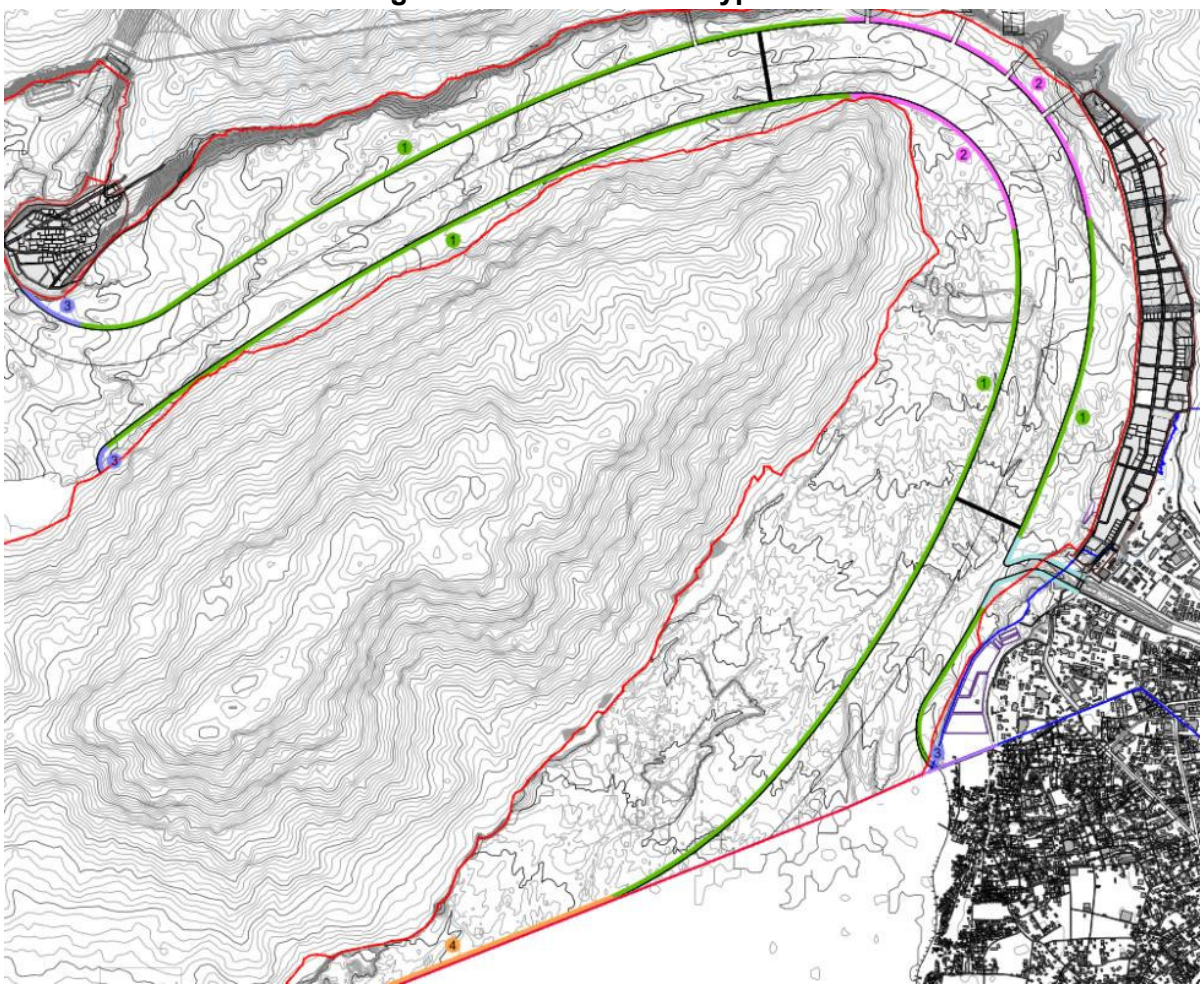
Figure 13: Wall type 4 (stone pitching)



Source: CDCL drawing BM-ZP-09 12/8/16

39. *Extents of each Embankment Type.* The extent of the embankment types shown in Figures 10, 11, 12 and 13 are shown in Figure 14.

Figure 14: Extent of wall types



Source: CDCL, Stage 3: Integrated Detailed Project Report (IDPR) – 2nd Draft, 12 August 2016. Main report. Fig 4.98

40. *Scour protection options*. The river banks, and all in-river works, must be protected from erosion and scour. There are *several* options for protecting the river bank toe from scour.

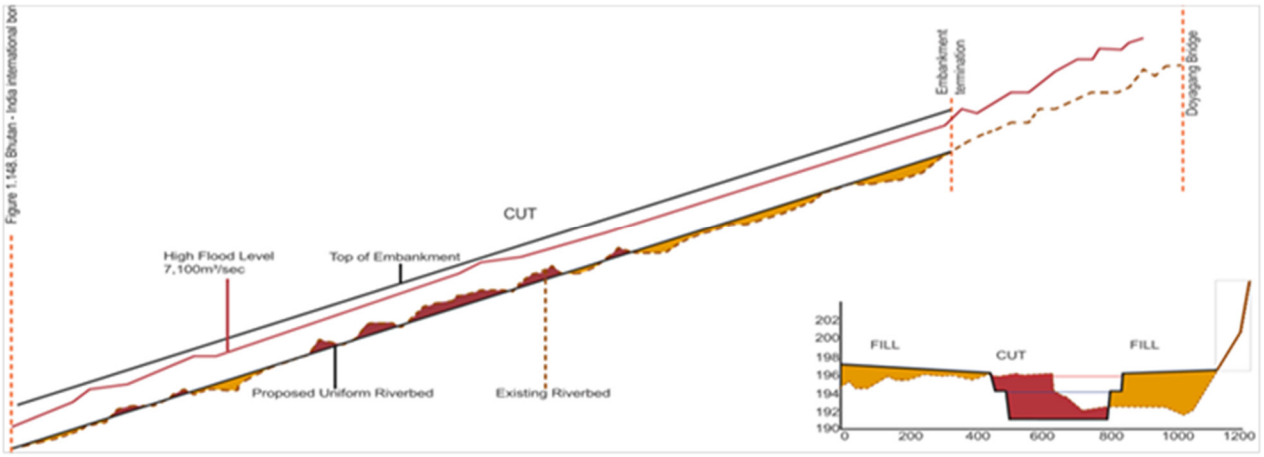
- Diaphragm wall – a vertical reinforced, cast in-situ, concrete retaining wall, well embedded at the toe and tied back at its upper edge to provide structural support in anticipation of scour removing material on the riverside of the wall. It is constructed in a top-down manner using a hydraulic grab to excavate and bentonite to hold the excavation open during placement of the reinforcing cage and subsequent concreting by the tremie method.
- Launching apron - a flexible rock/ stone apron constructed on the bed of the river which settles into the scoured area as scouring takes place and covers the base and side of the scour hole, preventing it from developing further. They can comprise large rock or stones in wire creates.

41. There are advantages and disadvantages of each option from a cost, durability and aesthetic perspective. CDCL ultimately adopted diaphragm walls for the majority[24] of the river training works. This option is appropriate due to the relatively high design velocity. It is recommended that a specialist contractor be contacted to discuss the practicality of excavating in coarse alluvium. There is a programme risk if very coarse sediment/ boulders are encountered by the grab at depth during excavation. The boulders would require splitting prior to excavation, which would slow the production rate. CDCL advise that this has been discussed with *a couple of contractor's and no extraordinary risk is perceived* and that the risk is captured in the project risk register.

42. *Channel formation*. The existing natural riverbed is irregular in cross section and long profile. The overall gradient is *fixed* by levels at each end of the project. CDCL propose to regrade the river bed by undertaking cut and fill along the channel to form a uniform initial bed gradient. Similarly, cut and fill will be undertaken across the channel to form a prismatic channel, with the excess cut material used for engineering fill behind the proposed training works. Figure 15 shows the concept in long section and cross section.

[24] A diaphragm wall isn't proposed for the Type 4 wall where scour risk is relatively low.

Figure 15: River bed re-grading



Source: CDCL, Stage 3: Integrated Detailed Project Report (IDPR) – 2nd Draft, 12 August 2016. Main report. Fig 1.152

43. *Deposition.* For Zone A only, sediment deposition within the channel will take place much the same as it currently does. The notable differences are that the channel will narrowed due to the reclaimed area on the left bank, and the deepest part of the channel can be expected to follow the diaphragm wall alignment throughout the bend. River morphology within the trained section will be examined using the 2D model for the entire development. There remains a risk of sediment deposition within the channel resulting in increased flood levels for a given event. The probability cannot meaningfully be calculated as there are many scenarios, including multiple floods in which, for example, a 1 in 10 AEP flood[25] deposits a significant amount of material in the channel on the tail of the flood hydrograph (when most deposition takes place). A second flood could conceivably follow before any sediment dredging/ redistribution work is carried out. The consequences in terms of flood water surface elevations depend on: a) the quantity and location of the deposited sediment due to the first flood; b) the magnitude of the second flood, and c) the 'sluicing' power[26] of the second flood; d) the sediment load in the second flood; and e) the hydrograph shape/duration. It is relatively time consuming to investigate the scenarios using the 2D mobile bed model but that is still recommended. Simplified methods have been used to test the hypothesis that deposition will be problematic. These include consideration of competent velocity and comparison of stream power under existing conditions and the proposed conditions.

- Making some simplifying assumptions,[27] and using Shield's criteria to establish threshold movement conditions, the Frequent Flood, 1 in 50 AEP and 1 in 100 AEP floods should be able to mobilize all material up to 100mm, 175mm and 200mm nominal diameter respectively. Larger material can of course be moved if the 3D velocity field is considered.
- Making some simplifying assumptions,[28] it is estimated that stream power of the proposed channel will be between 30 and 70% more than the existing channel during the peak discharge associated with the 1 in 100 AEP flood.

[25] This is a nominal event. It could be less or more, but it needs to be sufficient to mobilise material from upstream. A flood as low as the Mean Annual Flood (approximately 1 in 2 AEP) should be able to readily do that.
[26] Stream power (energy lost per unit length of channel) and associated mean bed shear stress.
[27] Assumes: 1) a rectangular channel as the 'edge' effects due to the side slopes are insignificant for the present calculations 2) uniform flow.
[28] Assumes: 1) again, rectangular channels; 2) a base width of between 600m and 800m for the existing channel (the lesser width gives rise to the 30% mentioned above) and 300m for the proposed channel.

44. Based on these simple checks, making a deposition allowance when estimating the design flood levels in the Amochhu is not recommended. This will be reviewed for the entire development within the 2D model study.

45. Deposition is also separately evaluated/ considered for design of the cross-drainage facilities. It is conceivable that deposition will take place in the 'first' flood mentioned above, and given the potential for cross drainage floods to take place whilst the Amochhu discharge is relatively low (i.e. due to localized storms in Phuentsholing), the 'sluicing' power of the Amochhu during the 'second' flood cannot be relied upon to mobilise the deposited sediment at the exit to each cross-drainage facility. This highlights the maintenance vigilance needed during the monsoon for the cross-drainage facilities.

5. River Impacts

46. *Impact of the Ultimate Development on the Amochhu in the Project Area.* The river training works do not include abstractive uses or facilities to store water so there will be no impact on river discharge (volume) during construction or after development. Sediment discharge will be similarly unaffected.[29] The river training works will have an impact on water level and velocity but these impacts will only materialise in practical terms during floods. Post implementation of the entire development, water level during floods may be slightly higher or lower than under existing conditions. The difference depends on location, but is expected to be within 300mm of existing flood levels. Post development, the cross-section averaged velocity during floods will be higher than under existing conditions. From a channel morphology perspective, it is anticipated that a braided river will re-form within the 300m river width during each dry season and be further changed during each wet season. Inevitably there will be some very small changes in depth and velocity distribution within each braid during the dry season, but the changes are not significant in such a dynamic alluvial environment.

47. *Impact of Zone A only on the Amochhu in the Project Area.* The impact on flow depths and velocities with only implementing river training works on the left bank for Zone A, pending further development or as the only development, will be similar to that described for the ultimate development but smaller in magnitude. The main differences are that the river channel will not be confined within the ultimately proposed 300m width and that the bed gradient is unlikely to be uniform at the end of construction. Braid formation will continue. The thalweg[30] will generally form along the alignment of the training works, throughout the sweeping bend and for some distance downstream of the bend, as the training wall forms a rigid boundary.

48. *Transboundary Impact of the Ultimate Development.* Prior to implementing works on the true right bank (Zones C and E), a 2D model will be developed to quantitatively and qualitatively assess impacts on hydraulics, sediment transport and channel morphology downstream of the Indian border deriving from the project. Effects of developing all five zones on the Amochhu downstream of the border as far as Hasimara (circa 15 km downstream) were investigated quantitatively in the 2007 and 2013 DHI India studies. The following qualitative comments on transboundary effects can reasonably be made at this stage using engineering judgement and regarding the earlier quantitative work.

49. At a river 'reach scale' (i.e. river length 10 times the river width, or more), transboundary effects will be insignificant, principally because the development will not change the river

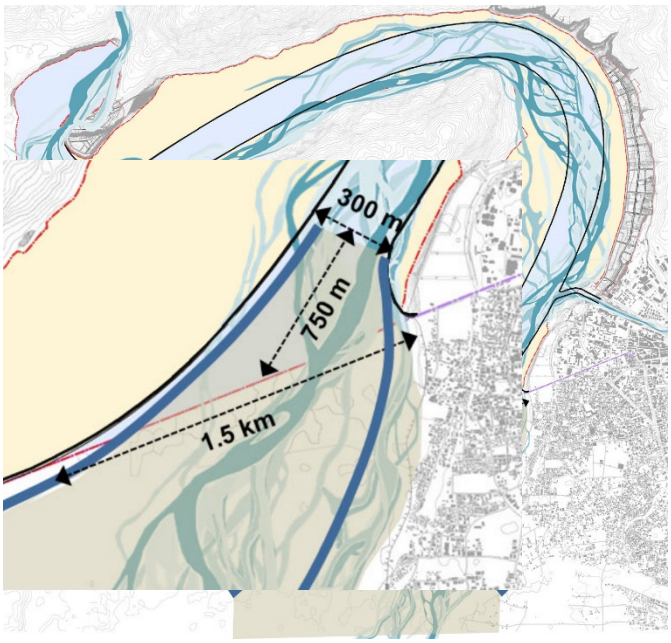
[29] When considered at time scales that are relevant to sediment flux in an alluvial river. The vast majority of annual sediment transport takes place during the monsoon season. The river training works won't change that.

[30] A line drawn in plan view which follows the deepest part of the river cross section.

discharge or sediment discharge[31]. The layout for the five-zone development has changed somewhat from the scheme modelled at the time of the earlier studies but the changes would not affect the conclusions at the reach scale.

50. At a 'local scale' (i.e. river length 1-2 times the river width, or less), there will be small changes to the velocity and flow distribution across the river, close to the India-Bhutan border at the downstream end of Zone A where the 300m wide channel transitions back to the full channel width. To minimise the changes the proposed alignment geometry includes the use of guide banks to streamline the transition at the end of the realignment. A modified embankment detail will be used where the embankment terminates at end of the training works in combination with the guide banks. The transition length is 750m, which at more than twice the trained channel width, should be adequate to distribute discharge across the channel width during bank-to-bank flow conditions. At lesser discharges the flow will follow, and form, braids.

Figure 16: Transition geometry



51. Jaigaon is currently vulnerable to lateral erosion along the true left bank, in the same manner as Phuentsholing is vulnerable upstream of the border. Examination of the dry season meander belt (Figure 7) shows that the dominant braid has migrated towards the true left bank through Jaigaon at least twice over the last 10 years. It moves every wet season as would be expected for high energy, steep gradient, alluvial river. The left bank in Jaigaon is presently unprotected from erosion and scour, apart from ad hoc attempts in selected areas using gabions which have proved to be a temporary solution only.

52. *Transboundary Impact of Zone A only.* The transboundary impact of only implementing river training works on the left bank for Zone A, pending further development or as the only development, will be similar to that described for the ultimate development but smaller in magnitude.

6. Land Development and Reclamation Works

53. *Borrow sites*. Using borrow sites that require haul trucks to pass through the existing town will have an unacceptable environmental and social impact. ADB's strong preference is that the material is sourced from within the Amochhu valley, as far as practicable, and to the west of it, including the borrow identified at Hourikhola. From a financial perspective, the use of suitable riverbed and landslide material from the immediate project area (without excavating below natural ground levels) should be prioritized. There is sufficient borrow materials available for the Zone A works. About 700,000 m^3 of the total of 2,483,000m^3 required for Zone A will be imported from

[31] Over time scales that are of interest for river morphology studies.

borrow sites within the valley. The remaining material will be won locally within the river bed and valley. The borrow sites are addressed in the EIA and restrictions in terms of transport needs are reflected in the bid documents.

54. *Large rock sources*. A significant quantity of large rock is required for placement adjacent to the cast in situ wall, as well as for use in any guide embankments required to protect the works during monsoon season prior to completion (if needed). The rock is for aesthetic and durability reasons (i.e. protects the cast in situ wall from abrasion). The rock will be sized appropriately to avoid it being mobilised downstream during floods.

55. *Processing.* The proposed location for processing imported material is within the project site. The EIA addresses the effects of processing at site, and at the borrow site(s) located outside the project boundary, if needed.

56. *Spoil sites*. There will be organic material and/or waste material produced during processing, including screened stones that are larger than allowed in the fill specification. Additionally, some of the debris fan materials may be a source of fill, or will need to be cut to waste (i.e. spoiled) to achieve the required formation levels. The debris fans contain organic materials (timber etc.) as well as weathered materials which would not be used as fill. The proposed location for disposal of unsuitable earthworks materials will be determined by the Contractor and spoil sites are identified and assessed in the EIA.

57. *Grading.* The final fill formation level will be graded (longitudinal and horizontal) to facilitate controlled surface runoff, leading to the stormwater collection system. It is important for all Zones, but particularly for Zone A as the stormwater system will be installed in works package CW-02 (i.e. there will be a delay between works package CW-01 completion and the installation of the system).

7. Cross Drainage Works

a. Zones B, C and E

58. *Design responsibility.* CDCL are responsible for the design of any cross drainage for Zones B, C and E. Zone B includes ducted outfalls 9, 10, 11, 12 and 13. Zones C and E do not include cross drainage as the runoff has been considered as stormwater and is described in Annex 7 of the IDPR (Common Urban Infrastructure). The following discussion refers to the design of Zone B.

59. *Tributary flood estimates.* No flood estimates are reported for Zone B. It is recommended that the flood estimates are derived using the rainfall IDF/DDF relationships provided to CDCL in December 2016.[32]

60. *Hydraulics.* No backwater calculations are provided for the cross-drainage facilities. Water surface profiles for each cross-drainage structure should be calculated and plotted assuming the design flood discharge in the cross-drainage duct/channel and a concurrent flood condition in the Amochhu, in line with the design criteria provided to CDCL in December 2016.

61. *Sediment transport.* No sediment transport calculations are provided for the cross-drainage facilities. Sediment transport calculations *are* required for each cross-drainage facility.

[32] PPTA, *Cross drainage*, memorandum from C Dunlop to K Dhakal, 21 December 2016.

b. Zone A

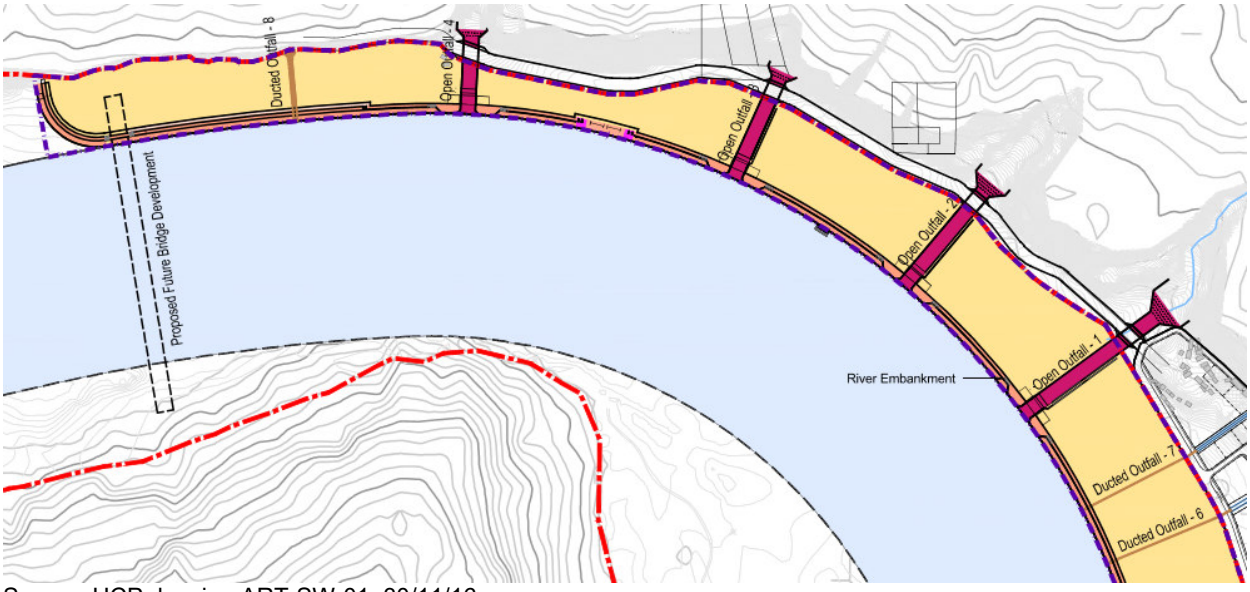
62. *Design responsibility.* DOR has undertaken detailed designs for the Phuentsholing-Chamkuna Road (PCR) Project which forms the eastern boundary of Zone A. It was agreed between CDCL and DOR that DOR are responsible for the designs of all cross drainage works upslope of the PTDP boundary in close coordination with CDCL, who remain responsible for the cross drainage works between the PTDP boundary and the Amochhu.

63. *Cross-drainage interface.* The success of the PTDP cross-drainage works depends on having appropriate structures constructed as part of the PCR project (including debris traps) and subsequently being well maintained. CDCL have agreed key functional requirements with DOR, and the designs are in progress.

64. *Zone A cross drainage changes.* CDCL's design originally proposed ducted outfalls labelled 1-8 and open outfalls labelled 1 to 4 in Zone A. Figures 17 and 18 show the locations. A blockage risk was identified for the ducted outfalls due to sediment transport from the tributary fans. Following several meetings with DOR and CDCL, it was agreed that ducted outfalls 3, 4, 5 and 6 would be changed to open channels.[33] The master plan was updated accordingly at the end of January.

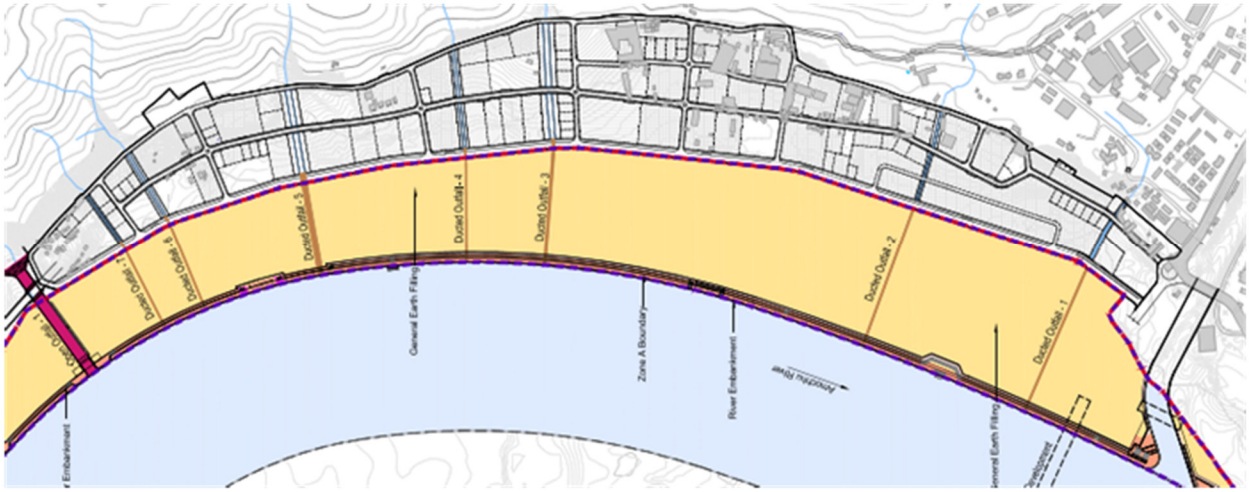
[33] PPTA, *Cross drainage recommendations*, memorandum from C Dunlop to K Dhakal, 9 February 2017.

Figure 17: Zone A cross drainage plan (1 of 2)



Source: HCP drawing ART-SW-01, 30/11/16

Figure 18: Zone A cross drainage plan (2 of 2, rotated)



Source: HCP drawing ART-SW-01, 30/11/16

65. *Maintenance.* The maintenance regime for the PCR structures and channels in the Amochhu LAP require formalising, particularly for managing debris. The Thromde will ultimately be responsible for maintenance of the open drainage channels in the Amochhu LAP area and the DOR will be responsible for the structures local to the road. Responsibility for the debris traps, if provided, needs to be clarified.

c. LAP

66. *LAP interface.* The PTDP cross drainage structures provide 'indirect' interfaces between the PTDP and the LAP at seven discrete locations. See Annex 1 for plan and sections.

67. *LAP filling.* CDCL's present design assumes the LAP will be filled along most of its length, with some excavation/levelling at the northern end. Open channel drains will be formed by excavation in the engineered fill (presumably) to guide the existing drains into the proposed

'ducted' outfalls. This work will be undertaken by the Thromde with support from the PCR project. In the absence of filling, the issues are:

- ponding of local drainage within the LAP area due to a mismatch in levels between the proposed culverts and existing ground levels[34]
- ongoing deposition of debris flow into the LAP area with no reasonable prospect of it being sluiced into the river,[35] due to the proposed level of the PTDP creating a barrier
- exposure within the LAP to river flooding via backflow through the seven PTDP ducted outfalls[36]
- exposure of PTDP to uncontrolled secondary overland flow[37] derived from hill slope drainage during localized storms. The overland flow would result in inundation and surface scour of the finished building platform, which clearly wouldn't then be suitable for development.

d. Other Phuentsholing Thromde Areas

68. *Filling.* The comments made regarding the LAP area apply equally to the Phuentsholing Thromde administered area between the Omchhu and the STP. See Annex 2 for plan and sections. Filling of this area is an interface issue with technical feasibility implications.[38] There are several buildings and items located in the 'green' area shown in Annex 2, including:

- Communications tower
- Overhead power distribution lines
- Basketball court (Nazhoen Pelri YDF) and grey metal clad building
- Several recently constructed buildings on the low terrace towards the river
- Workshops and truck parking lots

69. It is unclear how many of the above items are formal (i.e. approved and intended to be permanent), particularly given the 30 m set-back that is meant to be adhered to under the Water Act of Bhutan 2011. The Thromde will investigate the feasibility of this filling.

8. Urban Stormwater Works

70. *General.* The stormwater works are relatively standard infrastructure that should be designed in accordance with drainage design standards, local planning guidelines,[39] and codes of practice.[40]

71. *Flood estimates.* It is recommended that the flood estimates are derived using the rainfall IDF/DDF relationships provided to CDCL in December 2016.[41]

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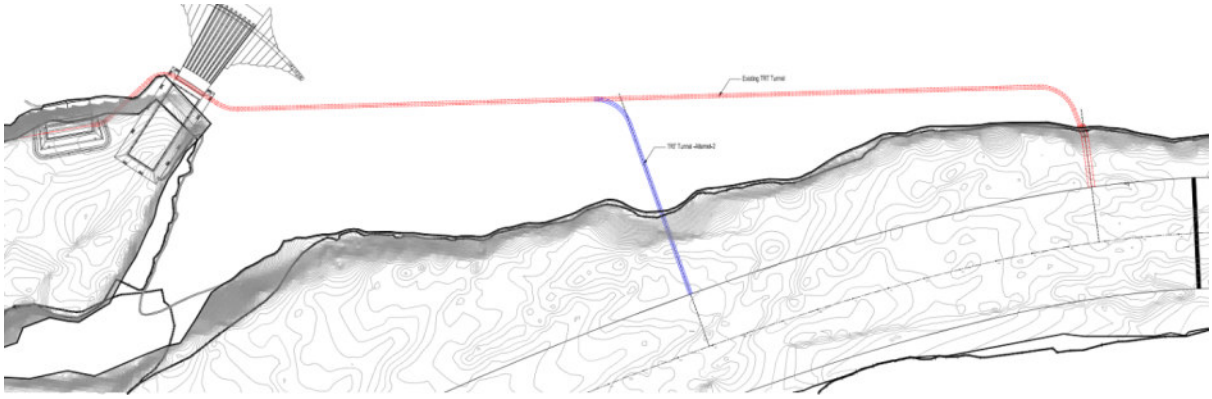
[34] 'Local' includes the hills to the east of the LAP which are steep, and unstable in places, resulting in flashy flood and debris discharges
[35] Evacuation of debris material presumably currently takes place, to a limited degree, but periodically requires removal and disposal by mechanical means. Supply far exceeds transport capacity.
[36] A 2014 Amochhu LAP report says that ALDTP will protect the LAP from river flooding. Phuentsholing Thromde, *Amochhu LAP Land and Plot details, and Report*, 2014.
[37] This would happen if the open channels in the LAP are not formed as shown on the drawings, and/or if the channels/culverts become blocked due to debris collection.
[38] PPTA, *PCC land drainage*, memorandum from C Dunlop to L Gore, 12 February 2017
[39] Ministry of Works and Human Settlement, *Guidelines for Planning and Development of Human Settlements in Urban and Rural Areas of Bhutan to minimise environmental impacts*, June 2013
[40] NEC, *Environmental Codes of Practice for Stormwater Drainage Systems*, 2004
[41] PPTA, *Cross drainage*, memorandum from C Dunlop to K Dhakal, 21 December 2016.

9. Amochhu HPP

72. *Amochhu HPP*. The Amochhu Hydro Power Project was studied by in September 2011 for the Department of Energy, Ministry of Economic Affairs. A Detailed Project Report (DPR) was prepared resulting in a concept design for a 4x135 megawatt scheme with a 195m high Concrete Gravity Dam proposed *just* upstream of the Doyagang Bridge.[42] It includes a Tail Race Tunnel (TRT) that would have an outfall towards the downstream end of Zone B, approximately where Zone A presently starts. Figure 19 shows the general location (the TRT in red).

73. The Amochhu HPP is not related to the PTDP and its planning status, beyond preparation of a DPR, is unknown. However, its implementation would have material impact on PTDP and hence it is considered briefly here. Simplistically, the positive effects include a degree of flood attenuation and a 'smoother'/ more controlled discharge regime. The negative effects include reduced sediment discharge, leading to lowering of the channel, and the incremental public risk posed to PTDP by to the dam. CDCL is not able to provide an update on the probability of the hydropower project proceeding, or a likely implementation program. Accordingly, the precautionary principle must apply. PTDP must be designed taking account of the hydropower project which includes allowing for integration of the tailrace tunnel in Zone B, and allowing for river morphology changes in the design of the diaphragm wall, amongst other things. The changes in hydrology should not be included.

Figure 19: Amochhu HPP location



Source: HCP drawing DE-TA-14

C. Overall Design Conclusions

74. The project is technically viable. From a functional perspective, the project components are generally arranged and proportioned such that they can reasonably be expected to operate in the manner intended provided a rigorous maintenance regime is followed. Several important aspects, including but not limited to river hydraulics, sediment and river morphology, cross drainage, and boundary interfaces, have been assessed and included in the detailed designs as per the recommendations provided in this report. The 2D model results, when made available, will assist CDCL with either validating the detailed designs as described in this report or guide design amendments. Based on the information available the engineering design will conform to accepted local and international practice, and design principles commensurate with the size and value of the project.

[42] NTPC, *Amochhu Reservoir Hydroelectric Project – Detailed Project Report*, September 2011.

III. Implementation

75. A review of the CW-01 documents for Zone A was undertaken in late January 2017. The recommended changes were conveyed to CDCL for implementation.

A. Key Findings

76. The first civil works package will be procured using international competitive bidding using ADB's standard bid documents for large works, which use the *Conditions of Contract for Construction for Building and Engineering Works Designed by the Employer*, Multilateral Development Bank Harmonized Edition, prepared by the Federation Internationale des Ingenieurs-Conseil or FIDIC (MDB Harmonized Construction Contract, June 2010).

77. Use of a FIDIC form of contract which requires an Employer's design, as proposed, requires the detailed design to be completed, the technical specifications to be thorough, the BOQ to be comprehensive, and drawings which are 'fit for construction'. It is effectively a 'build only' contractual arrangement which puts the onus on the designer to fully document the design.

78. *Drawings.* The drawings are at an appropriate level of detail. Changes will be required because of integrating the cross drainage works from PCR with PTDP.

79. *Technical specifications.* The specifications are at an appropriate level of detail.

80. *Bill of Quantities.* The BOQ is at an appropriate level of detail however, a list of general items should be included in the beginning of the table.

81. *Other information for bidders.* A list of additional documents that will be supplied to the bidders for information (e.g. 2007 geotechnical investigations, Borrow Area report etc.) is required.

82. *Design reports.* Detailed design for packages CW-1 and CW-2, which comprises the common urban infrastructure (roads, water supply, sewerage, etc.), must be adequately documented. This is particularly important due to:

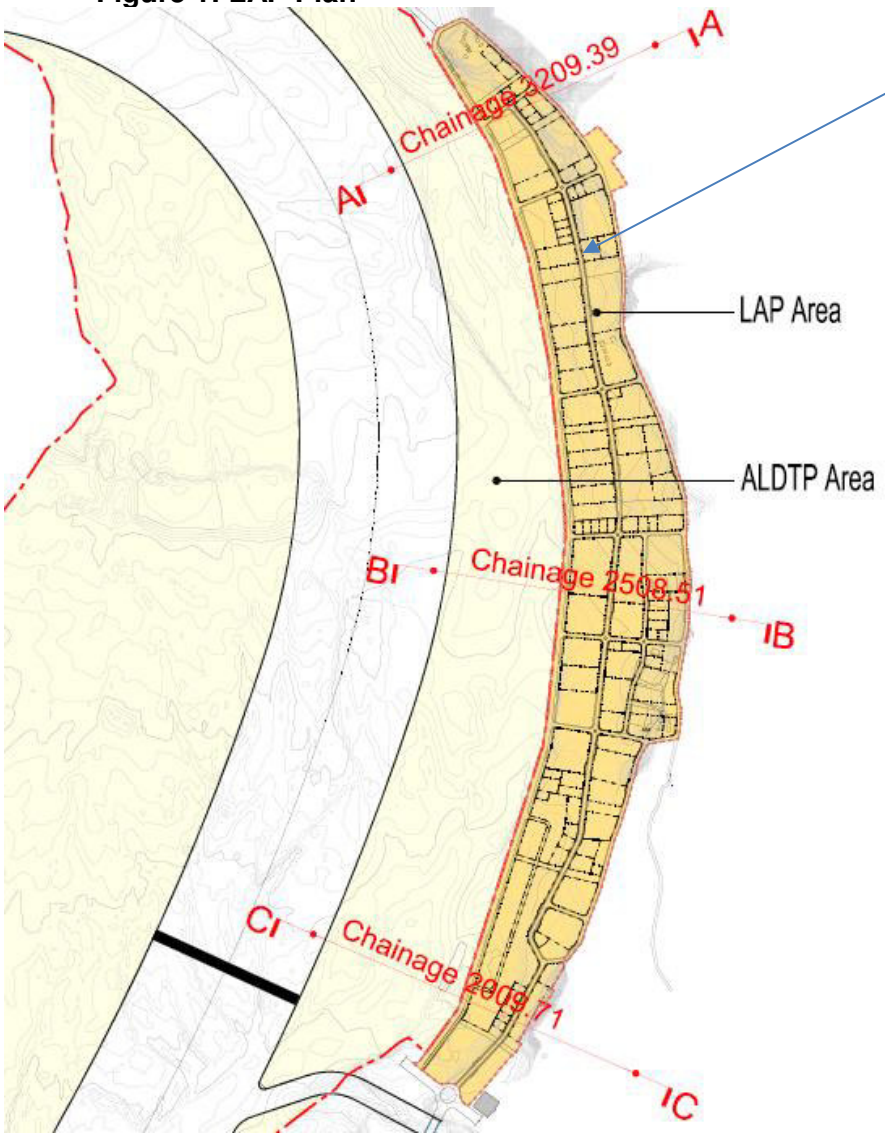
- the contractual split between the party responsible for the detailed design and the party responsible for the construction supervision
- the length of time likely between the end of detailed design and the start of construction.

83. It is recommended that design reports are produced for the various components/ systems, in line with normal practice, so that the key decisions are documented. This will be important during implementation when changes arise and the Construction Supervision Consultant is required to revisit the design to accommodate the changes. The design reports could be stand-alone documents or included as appendices to the IDPR. They should be consistent in terms of reporting the key design requirements, standards used, and calculations.

B. Implementation Conclusions

84. The documents are adequate for use in bid documents based on a FIDIC MDB Harmonized Construction Contract. If design changes are made either prior to or after contract award, it is recommended that the design amendments are undertaken by CDCL's design consultant. The timing for design changes is likely to preclude re-issue of drawings and BOQ during the bid phase, necessitating re-issue of documents after the contract award.

Figure 1: LAP Plan



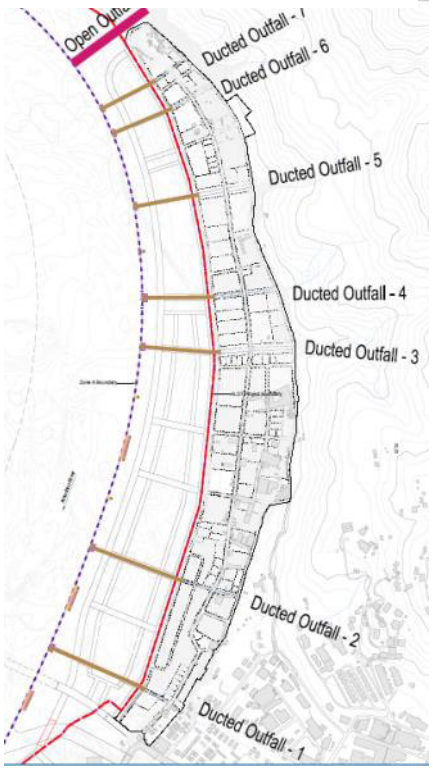
Source: HCP drawing CS-LAP-10 (11/07/16)

The PPTA's annotations are shown in the boxes below.

Fill volume required within the LAP area ~500,000m^3

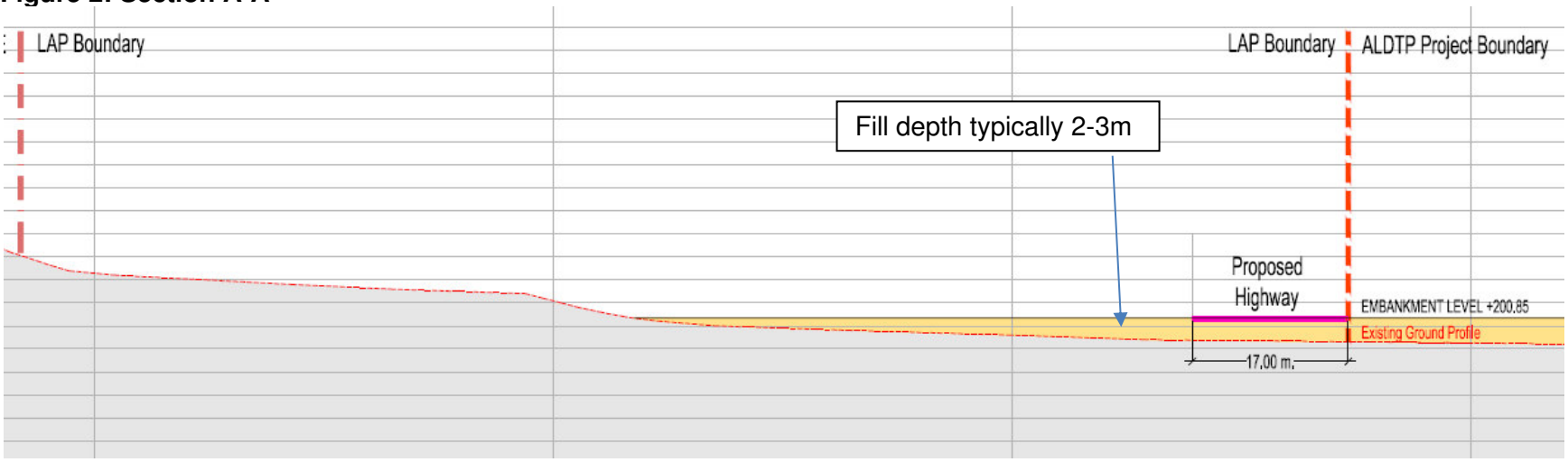
7 cross drainage channels pass through the LAP, connecting to the ALDTP ducted outfalls

Inset (NTS)



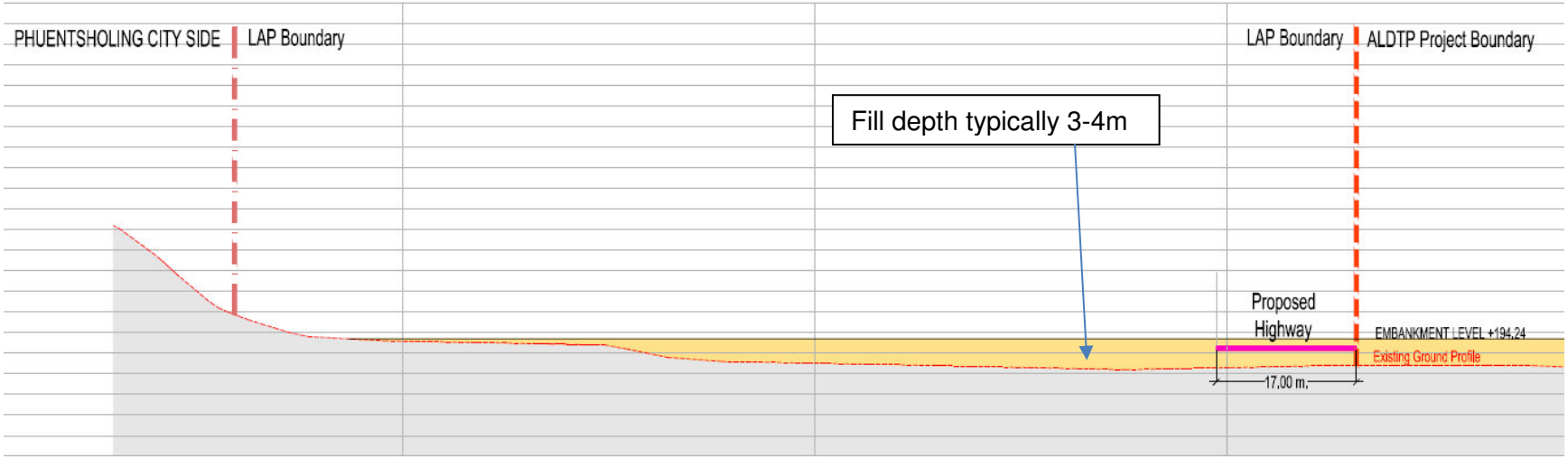
Source: HCP drawing AOF-LO-01

Figure 2: Section A-A



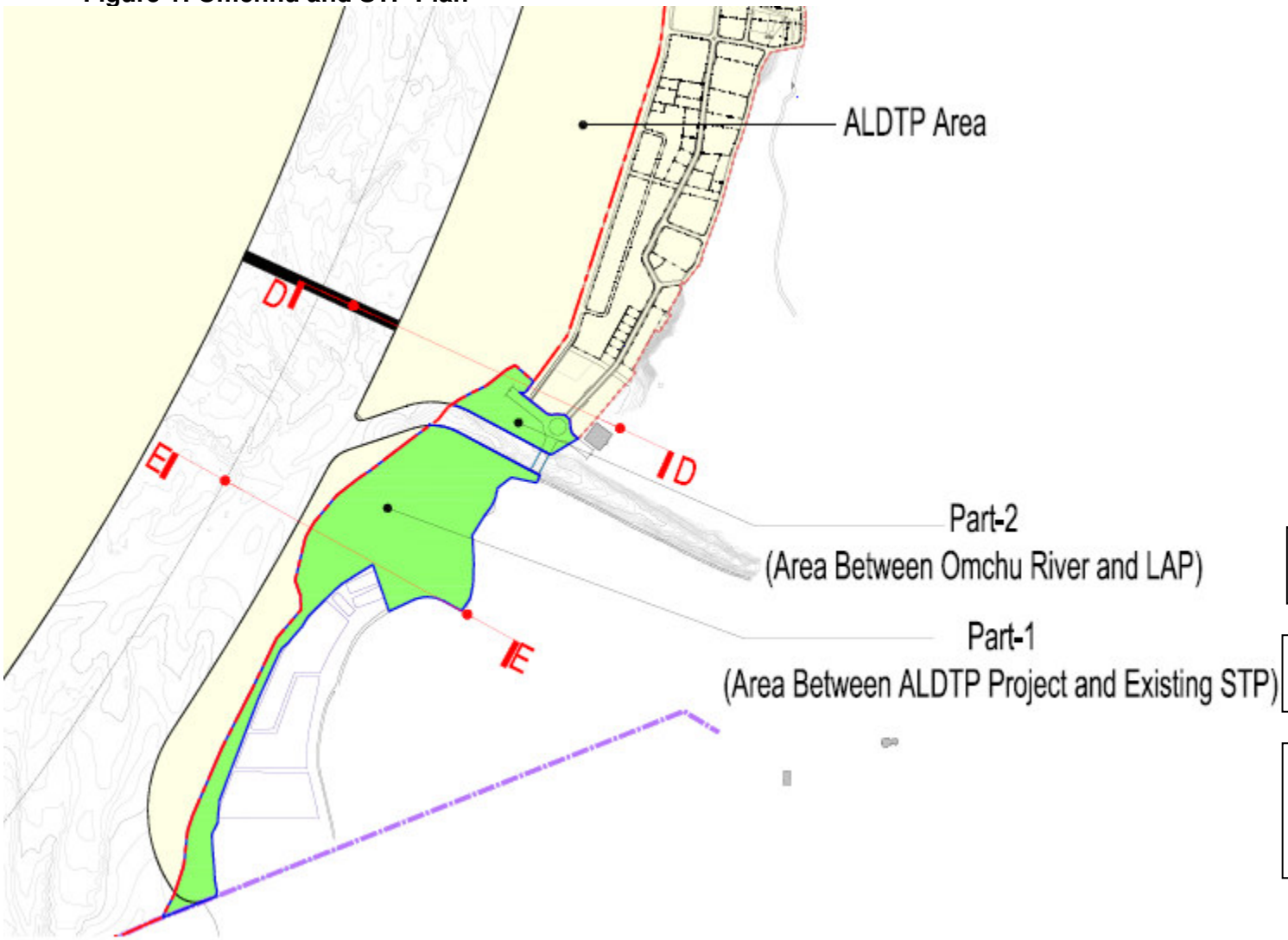
Source: HCP drawing CS-LAP-10

Figure 3: Section C-C



Source: HCP drawing CS-LAP-10

Figure 1: Omchhu and STP Plan



The PPTA's annotations are shown in the boxes below.

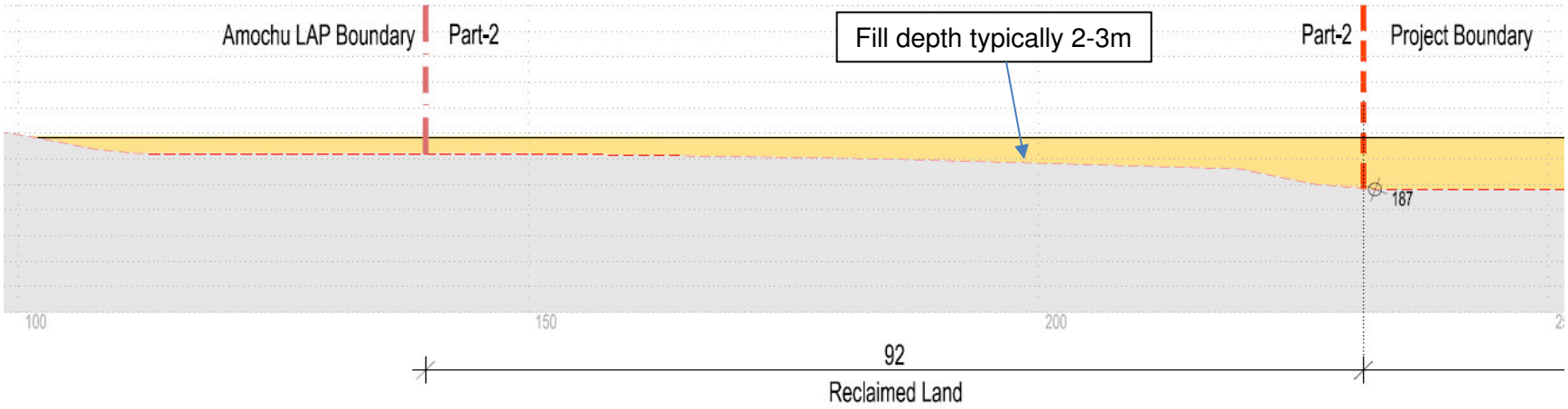
Fill volume required ~11,000m^3

Fill volume required ~152,000m^3

Surface drainage infrastructure proposed for these areas is unknown.

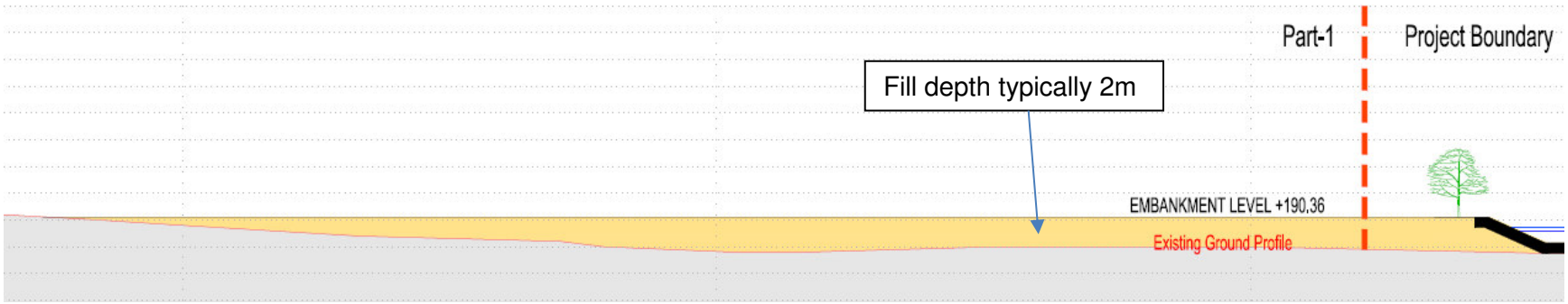
Source: HCP drawing CS-LAP-11 (11/07/16),

Figure 2: Section D-D



Source: HCP drawing CS-LAP-11

Figure 3: Section E-E



Source: HCP drawing CS-LAP-11

Technical Due Diligence - Part B
Urban Planning and Design

Table of Contents

Abbreviations and Acronyms

ADB	Asian Development Bank
ADF	Asian Development Fund Resources
BRT	Bus Rapid Transport
CAPEX	Capital Expenditures
CDCL	Construction Development Corporation Limited
CPS	Country Partnership Strategy
DHI	Druk Holdings and Investment Company
EIA	Environmental Impact Assessment
IDPR	Integrated Detailed Project Report
MFF	Multi-tranche Financing Facility
PPP	Public Private Partnership
PPTA	Project Preparatory Technical Assistance
PTDP	Phuentsholing Township Development Project
PUA	Phuentsholing Urban Area
ROW	(Road) Right of Way
SDG	Sustainable Development Goals
SME	Small and Medium Enterprises

Part B
Urban Planning and Design

1 Introduction

1. The Government of Bhutan, through the Construction Development Corporation Limited (CDCL), a subsidiary of the government-owned Druk Holdings and Investment Company (DHI), is interested in investing in the expansion of the city of Phuentsholing, Bhutan's main commercial center and cross-border connection point with India. Planned expansion includes new development on reclaimed land from the Amochhu river contiguous with the existing city, and a new town portion across the Amochhu River to the west. Total new population capacity may be in the order of 40,000 to 50,000 persons. This Due Diligence Report analyzes the urban planning aspects of the work to date and is based on a review of the government's feasibility study (August 2016), related field work and stakeholder meetings conducted during September 2016, and follow-up discussions held during January 2017.[1] Initial findings were discussed with the client in the field and this report expands on those points. Preliminary comments to, and responses received from HCP up to January 2017 are also incorporated along with additional comments received from key stakeholders.

2. In summary, the proposed Project is considered to be of significant immediate and future benefit to Phuentsholing, Bhutan as a whole, and to the larger region including nearby parts of India. The key starting point is the protection of existing Phuentsholing and potential future development lands through an extensive Amochhu river training and land reclamation investment.

3. The overall quality of the integrated detailed project report (IDPR) prepared by CDCL is found to be of high quality and professionally done. The IDPR covers the government's long-term township development program to develop five zones near Phuentsholing, Zones A to E. The Phuentsholing Township Development Project (PTDP) comprises only Zone A, however all five zones are considered in broad terms in this assessment. During the course of the stakeholder consultations a number of points emerged in all sectors that require further consideration. The key areas of urban planning concern addressed in this report include confirmation of effective demand; appropriate phasing of the project; appropriate land use, infrastructure and building standards; and the physical and institutional integration of old and new parts of the city. All of these issues are considered within the socio-cultural, economic and environmental contexts of Phuentsholing and Bhutan.

4. For ease of reference, the structure of this report follows that of the IDPR and should be read in conjunction with other sector Due Diligence reports.

2 Context

2.1 Urbanisation and Phuentsholing Urban Area (PUA)

5. Bhutan is following the global trend of increased urbanization as key to economic growth, and the proposed PTDP represents the largest single urban initiative in the country's history. However, PTDP is treated as a discreet commercial investment by DHI/CDCL. This impacts their interest and ability in dealing with the larger issues of integration with the Phuentsholing Urban Area (PUA), the region and the rest of the country, although the impacts will be considerable. PTDP will not operate in isolation and a much broader review of issues, opportunities and

[1] CDCL engaged a consulting firm to prepare the feasibility study and detailed designs for the ALDTP. The scope of the consultant's TOR includes d urban planning and infrastructure development work, among others.

constraints is recommended, whether through the PTDP initiative or separately by government and the Phuentsholing Thromde. PTDP will create large amounts of leasable land and buildings. A complete understanding of PTDP's potential, market demand, infrastructure investment needs, and impacts is difficult without a full regional assessment.

2.2 Rural-Urban Migration

6. Both existing and projected growth of Phuentsholing are tied, in part, to levels of internal rural-urban migration. Bhutan is experiencing considerable migration to urban areas and recognizes the importance of urbanization for social and economic growth. Bhutan is currently about 30% urban and projected to reach as high as 50% by 2030. Growth projections for developing future zones of the PTDP should not assume continuous rural-urban migration at recent rates, and should be projected realistically based on actual observed demographic trends.

2.3 Immigration

7. A key component of Bhutan's retention of valued cultural heritage has long been its strict immigration policies. While wishing to attract foreign investors and tourists from neighboring India and the rest of the world, government is very wary of negative influences and is unlikely to significantly change immigration policies in the near future. Government is wisely balancing the prospects of potential short-term economic gain with the longer-term integrity of the nation. Planning for Phuentsholing and its economic future must keep this in mind.

3 Vision and Objectives

8. The Draft IDPR sets out a clear set of objectives from which a series of sector visions is derived. A review of these considers them to be appropriate, consistent with global best urban practice trends and, if applied, will form a solid basis for evaluating and monitoring more detailed design/ development proposals. Some of the key vision terms noted include "resilient" and "inclusive". To these it is suggested that "competitive" be added as Phuentsholing and its Amochhu new town expansion seek to distinguish themselves from regional investment options and become the most attractive.

9. It is recognized that the IDPR envisages one large project with several Zones/ phases. This long-term vision is considered valid and worthy of pursuit assuming effective demand exists to ensure economic, financial and social sustainability. The majority of the following sections of the report are aimed at contributing to a viable, incremental phasing of the development in order to achieve the long-term vision.

4 River Training

10. Refer to Part A of this Technical Due Diligence report for a detailed discussion. Investment in river training is the first priority in order to establish a secure environment for both existing Phuentsholing and subsequent new urban development. At the same time, the Amochhu River is recognized as a potentially valuable urban asset attracting visitors and investments. This requires that hard engineering requirements be balanced and integrated with the softer human, urban amenity goals.

5 Township and Urban Development

11. Three areas of particular importance at the larger scale that require further detailed analysis are: confirming demand; phasing options; and overall development scenarios.

5.1 Demand Analysis. Scoping Effective Demand

12. Quantified demand analyses are required to justify the extent and form of development (phasing of Zones), and to support a viable investment timeframe/ schedule. There is considerable expressed demand, political and otherwise, for more economic development and related housing. An effective demand analyses will complement the investment strategy by providing substantiated quantitative data in two areas: is Phuentsholing a competitive investment location?; and, what is required to achieve that? Terms of reference have now been prepared to undertake a Demand (Market) Analysis, using ADB technical assistance resources which will be completed before further zones are developed. The technical assistance will analyze effective market demand from the private investment sector for commercial and industrial development in the Phuentsholing area, including demand from small and medium industries (SME). A survey of national, regional and international investors will be undertaken to identify areas of investment interest, magnitude of potential investments, timelines, perceived investor advantages and disadvantages of the location (competitiveness), priority infrastructure and enabling environment requirements etc. Bhutan's existing investment, immigration and development policies must be taken into account. ADB's financial analysis has considered realistic or market based potential lease rates to ensure PTDP's financial and economic viability over the short, medium and long-terms.

13. An effective demand analysis will be followed by the start of an aggressive marketing program (funded under the loan) to attract inward investment which CDCL will initiate in Q4 2021.

5.1.1 Population Projections

14. Projections to date have relied upon simple extrapolation of historic population growth rates, including current rates of rural-urban migration. Several other factors should be taken into consideration: global and regional population growth rates are declining; rural-urban migration will reach a saturation point in Bhutan with the flow tapering off at some point; urban populations have lower growth rates than rural, so the national population growth rate can be expected to decline as urbanization takes place. Phuentsholing has physical growth limits and these will impose a cap on growth at some point beyond which population growth will halt and other centers will have to take up any residual demand. Actual population growth will likely flatten over time rather than continue to escalate along the curves currently being projected. Projections should be reviewed in greater detail before developing further zones to work out a workable phased development strategy for the PTDP.

5.2 Development Phasing

15. Five zones are currently planned: Zone A as the most economically critical and to protect existing Phuentsholing from flooding and erosion (PTDP comprises Zone A only); Zone B as an up-river development pocket; Zone C as the major financial investment and core of the entire five-zone development; Zone D comprising the environmental protection of Kalieshwar Hill and associated nature based tourism activities; and Zone E as a narrow strip of ecologically-based development along the river Amochhu. All Zones form parts of the overall long-term vision with important mutually-supportive linkages that must be kept in mind as phased development proceeds. In support of achieving the long-term total development vision, two aspects of

development phasing must be considered: the individual Development Zones; and phasing within each zone. The Draft IPDR proposed simultaneous development of Zones A and C including all required river training, bridge link and primary infrastructure. Subsequent discussions suggest initial development of Zone A as a first priority for protection of existing Phuentsholing and to test effective demand for new development zones. Zone C will then follow immediately as demand warrants, as will Zone B. Zone D requires little or no investment, and Zone E will be finalized over time.

16. Detailed phasing of development within each zone must be demand-driven to limit unsupportable advance infrastructure investments. To maintain the desired holistic and inclusive nature of development, land use zoning should be planned to allow incremental development of holistic phases, i.e. phases that include living, work and play opportunities for a full socio-economic spectrum.

17. Phasing should allow maximum land development and leasing with minimum infrastructure. In other words, phases should be planned to be as contiguous as possible to avoid long stretches of infrastructure without supporting development. Under the current project (Zone A) this would imply leasing out land closer to Phuentsholing thromde first, before proceeding to lease stretches farther away. This will result in consolidated pockets which can be expanded incrementally based on demand.

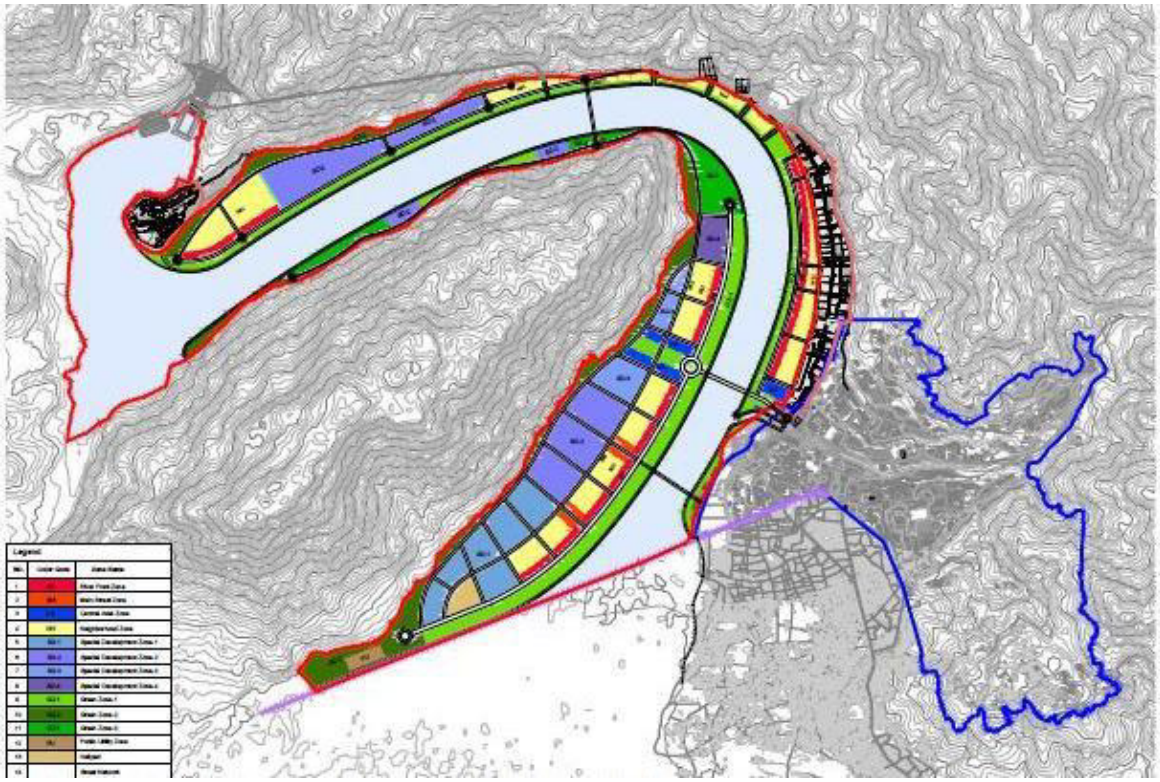
18. It should be emphasized that the key components of Zone A - river training and land reclamation - are considered essential for the social, economic and environmental well-being of existing Phuentsholing regardless of how other phasing evolves, and whatever the planning and land development details may ultimately be.

5.3 Development Scenarios/Alternatives

19. Draft 1 of the IPDR outlines a number of development alternatives based on various urban design concepts. Some integrate land uses, others separate them. The proposed Special Planning Area (SDA) run by the proposed Special Development Authority (under CDCL) is planned to be a prime attractor of investment, and consideration should be given to phase wise development in an integrated manner. Proposed Alternative 2 (Figure 1.) achieves that, while also providing for adjacent inclusive development of supporting commercial, residential and institutional uses.

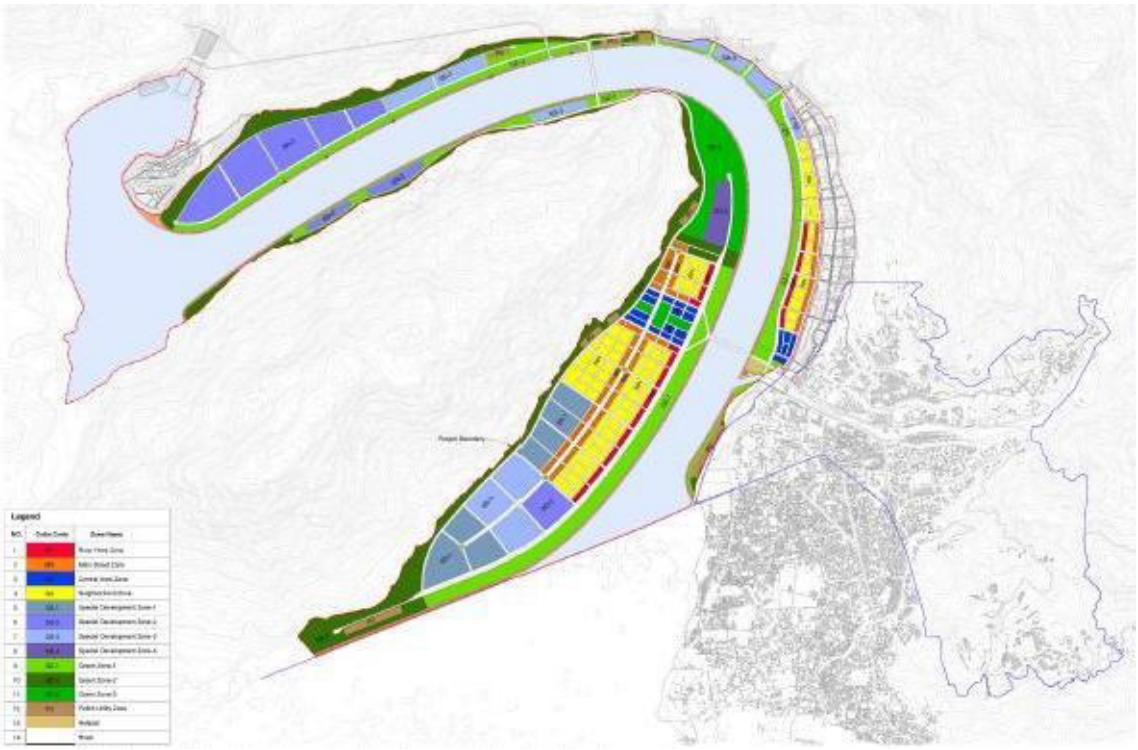
20. The selected approach in Draft 2 (Figure 2) comes closer to meeting the integrated, holistic needs at all development stages, but may still require significant infrastructure and residential build-out before the key plots are serviced. The zone must be developed incrementally based on market demand.

Figure 1: Draft 1 Development Alternative 2



Source: CDCL/HCP

Figure 2: Draft 2 Selected Planning Approach



Source: CDCL/HCP

6 Concept Master Plan

21. The following discusses a series of proposed urban planning details which have emanated primarily from discussions with CDCL and HCP.

6.1 Land Use Distribution

22. Amounts, proportions and spatial distribution of various developed urban land uses (residential, commercial, industrial, institutional, public open/recreational, etc.) are proposed. A quantitative effective demand analysis will support and guide detailed land use and related infrastructure planning. The demand analysis (para 12) will also help define land use details such as the splits between large-scale formal sector commercial demand versus small and medium size formal enterprises (SME), and small-scale informal sector demand. Residential split will be worked out based on close observation of population trends. These all have impacts on phasing and the appropriate forms of infrastructure to provide.

6.2 Infrastructure - Single-Loaded

23. The proposed design of Amochhu new town is attempting to balance development of a unique and high standard location with economic and financial viability. Two points of infrastructure design efficiency and affordability are raised: (i) the use of single-loaded street infrastructure; and (ii) the street design standards. Both points are being addressed by CDCL in their final IDPR.

24. Single-loaded street development is proposed along the riverfronts in Zones A and C based on the argument of better public access to the river amenities, and possibly more attractive land/ building leasing. These arguments may be valid, but three potential issues of affordability and financial viability are raised for consideration:

a) Single-loaded development reduces leasable land and consequently reduces the financial contribution to infrastructure costs, and therefore viability, unless significant lease rate increases are possible on the single developed side;
b) Revenue to support on-going infrastructure operations and maintenance (O&M) will be significantly reduced thereby increasing the financial burden on the responsible management agency(ies);
c) The option of increasing lease rates to off-set the revenue loss requires a market demand/ sensitivity analysis to determine if this is viable or will it instead serve as an investment disincentive.

25. CDCL have reviewed these concerns and reached the conclusion that single-loaded is the preferred design option for a model township, and can be financially accommodated. The effective demand analysis should provide further evidence. If there is the possibility of wishing to add double-loaded development at some future point as demand warrants or higher financial returns are sought, initial planning is required to ensure adequate river setbacks and infrastructure capacities.

6.3 Street Design Standards

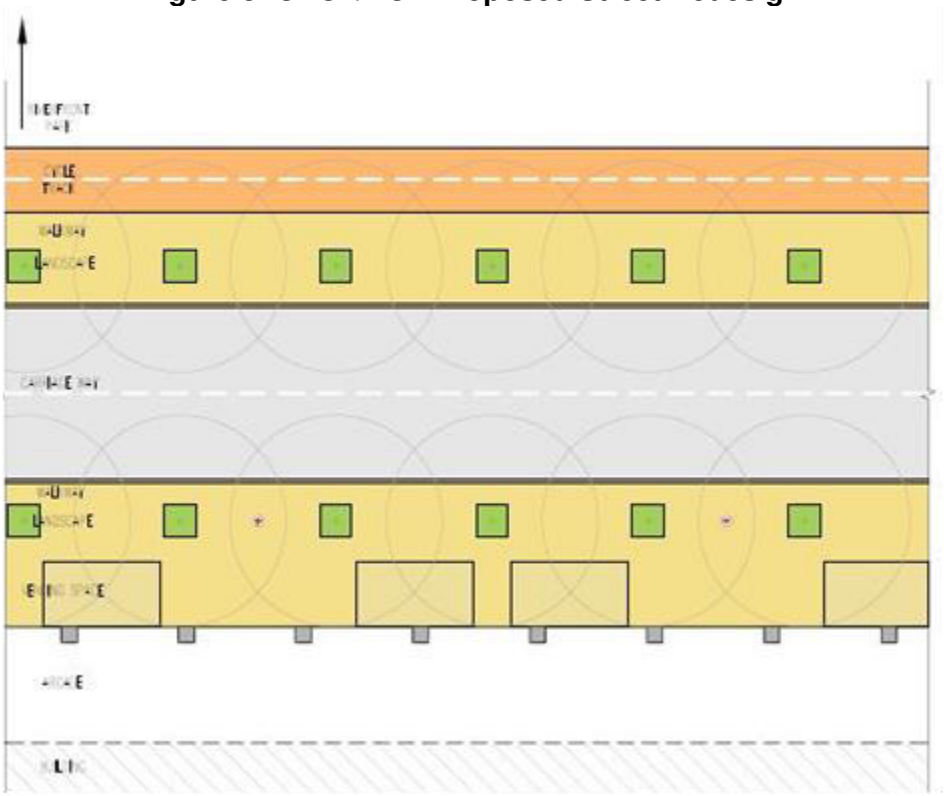
26. Street design standards proposed in Draft 2 (up to 42m ROW) are considered to be 30-50% over-designed given the small town context; the need to maximize leasable land in the confined

parameters' high infrastructure costs; high long-term O&M costs; and the likely nature of public transport. Note that dedicated BRT lanes as initially suggested for at least Zone C are not likely justifiable in this small town setting. No traffic forecasts have been prepared to support the proposed street designs, and Zone C will have only local traffic without the through traffic experienced by Phuentsholing's existing core. Suggestions to reduce street standards have been accepted by CDCL in their latest master plan. To further support all road/ transport planning and design decisions, a comprehensive traffic management study is included in the scope of the project implementation consultants (PIC).

27. In all cases, detailed design attention should be paid to ensure street spaces are inclusive and provide appropriate space for the full range of users such as informal vendors/ small kiosks and these are being incorporated by CDCL in the final IDPR.

Source: PPTA team

Figure 3: CDCL/HCP Proposed Street Redesign



Source: CDCL

6.4 Block Dimensions - Secondary Infrastructure and Leasing

28. The master planning gives flexibility to accommodate a range of lot sizes depending on subdivision of larger lots. It is proposed that the riverfront facing plots will not have any setback from the main street and can be subdivided into minimum units having 24m frontage each. The planning also provides flexibility to combine lots or undertake developments in larger lots as per guidelines prescribed in the proposed development control regulations (DCR). In case a single developer takes possession of a larger lot then the developer will have to provide additional secondary infrastructure investment to make the blocks fully useable. However, this is not

considered as a development disincentive as the lot demarcation process offers flexibility to cater to a variety of market needs.

6.5 Green Space

29. Providing urban green space is a key design component of the project, and one that will undoubtedly be appreciated by most users/ stakeholders. Existing Phuentsholing is short of this type of amenity, and the riverfront in particular provides good opportunity. At the same time, spatial limitations and financial/ economic considerations must also be taken into account. To balance this, the IDPR recommends only the minimally required 30 meters setback as green space. This will provide adequate amenity value to the residents and will not entail a significant O&M burden on the proposed Special Development Authority which will manage the PTDP operations. The road infrastructure will be constructed outside the 30m green belt, and with a 15-18m road ROW. . In addition, the focus will also be on providing smaller-scale urban green spaces within the neighborhood precincts (small pocket parks). Opportunities for PPP sponsorship, a globally common approach, of these amenities could be explored for these pocket parks.

30. Kalieshwar Hill is protected as Zone D in the planning and provides an excellent large-scale green space backdrop to Zone C. Zone D may also be used for the development of nature based tourism activities such as eco/ wildlife resorts and nature/ hiking trails. The present design calls for a rainwater runoff/ flood management green space along the base of the hill which is to also serve as a public amenity. It is recommended that this space is designed using the concept of sustainable drainage system (SUDS).

6.6 Building Standards

31. Bhutan has carefully developed a strict and comprehensive set of development and architectural guidelines, which are diligently followed throughout the country. Existing Phuentsholing is a partial exception with its mix of Bhutanese and Indian styles. The traditional architecture is one of Bhutan's tourist attractions and an important element of cultural cohesion. The existing mix of styles in Phuentsholing detracts from its visual appeal, and should be avoided in PTDP. Proposals are being made to increase allowable height up to G+9 (in Zone C).[2] These recommendations have been put together in the form of a detailed DCR document, which will be put forth for approval to government along with the proposal for institution of special planning area and Special development authority (under CDCL) for PTDP. CDCL is currently in discussion with Phunetsholing thromde regarding establishment of procedures to review planning applications and issue planning approvals for the PTDP.

6.7 Bridge to Zone C

32. The original bridge design crossing the Amochhu and connecting Phuentsholing and Zone A with Zone C was proposed with 4 traffic lanes plus pedestrian/ bicycle space. This is considered to be over-designed and the suggestion was made to reduce the overall width of the bridge to accommodate 2 traffic lanes plus pedestrians and bicycles. HCP has taken these considerations on board which will be incorporated in the final IDPR. The pedestrian/ bicycle space will be treated as a continuation of the riverfront infrastructure. The forms of non-motorized traffic (pedestrian and bicycle as well as wheelchair) will be provided on both sides of the bridge. There will be no through traffic to-from Zone C, and a detailed traffic projection study will be undertaken (under

[2] The DCR proposes permissible height limit of G+5 in Zone A.

the scope of PIC) to confirm actual requirements. The second proposed bridge linking close to the future Zone B will also absorb some traffic and should be factored into bridge designs.

6.8 Traffic Integration

33. There is a clear need to integrate a series of traffic/ transport interventions in the planning of PTDP. This involves more than the CDCL investment and area of direct responsibility, and requires integration with the Phuentsholing Thromde and national transportation authorities. The Zone C-A bridge, new Phuentsholing Chamkhuna road, new dry port connection with possibly two bridges across the Omchu all converge within a few meters of one another with the potential for congestion, lack of safety, poor traffic flow and duplicated infrastructure. There are other traffic/ transport initiatives planned or underway within the PUA and across the border in India that will impact this particular project area and the links northward to Thimphu. A traffic management study to analyze these impacts and provide recommendations has been included in the scope of the PIC contract and will guide the development of future PTDP zones.

6.9 Phuentsholing –Chamkhuna Road (PCR) Integration

34. A new regional road is to be constructed from Samtse in the west and border the proposed Zones B and A before entering Phuentsholing and joining the Thimphu highway. The Ministry of works and human settlements (MOWHS) provided a decision that the alignment of this road will be between the PTDP and Amochhu LAP boundary (part of Phuentsholing thromde bordering the PTDP zone A). The edge conditions between PTDP and the PCR will need to be carefully designed to minimize noise and disturbance (including possibility of accidents) to the PTDP residents.

6.10 Urban Infrastructure Integration

35. Refer to a separate section of the Due Diligence Report for a discussion of integrating other common urban infrastructure components including water, waste water, solid waste, power, etc. There are numerous physical and institutional issues to resolve for the efficient operation of all services. A Strategic Action Plan to outline the split of roles and responsibilities between the thromde and ALDPT Special Development Authority has been proposed.

6.11 Institutional Integration

36. The current proposal for PTDP is that it will be developed and managed by DHI/CDCL as a separate urban area through the institution of a Special Development Authority. The remainder of the PUA will remain under the management of the Phuentsholing Thromde. There are numerous issues of integration that need to be considered. There will inevitably be shared infrastructure, shared demands on services, shared impacts both positive and negative, shared opportunities and constraints, and establishing some form of coordinating and problem resolution/ mitigation mechanism will prove essential. This is a first of its' kind development in Bhutan which is intended to be managed by an authority other than the thromde. CDCL are undertaking a series of consultations with Phuentsholing Thromde and MOWHS to work out issues such as splitting user fees, planning approvals, sharing of urban services/ infrastructure, land registration and property tax management between the two different entities. ADB is supporting CDCL to resolve the legal issues associated with this style of township management, through the mobilization of a legal expert funded through ADB technical assistance resources.

7 Project Sequencing

37. Phasing is discussed above and will be further determined by actual market demand and cash flows. As discussed elsewhere, the detailed urban planning discussions presented above do not substantially affect the priority first phase investments in river training and land reclamation. These items should/ can proceed while subsequent planning and development details are completed. Even the recommended effective demand analysis would not significantly impact the urgent need to protect existing Phuentsholing with flood management investments, and safeguard the potential for future development.

8 Conclusion

38. The vision, concept and draft plans for developing the Amochhu new town offer positive social, economic and environmental opportunities to the city, nation and region. It is a major, long-term investment and deserves the time, effort and consideration of multi-stakeholder inputs to review all possible issues and concerns in an effort to ensure maximum benefits and sustainability. The due diligence comments provided here are part of that process.

Technical Due Diligence
Part C: Common Urban Infrastructure

Contents

Supplementary Report
Technical Due Diligence
Part C: Common Urban Infrastructure

1 Introduction

1. This report records the technical due diligence review process and key findings related to the Common Urban Infrastructure (CUI) components of the project. CUI includes the provision of water supply, sewerage, roads, surface water drainage, solid waste management, telecommunications and power distribution.

2. The purpose of the technical due diligence review is to confirm that planning, engineering, and implementation details of the proposed project are done in accordance with established professional principles, practices and criteria, to allow final project evaluation and preparation of ADB project documents to proceed.

3. The review focused on the following main items:

- CDCL's 'Stage 3: Integrated Detailed Project Report (IDPR) – 2nd Draft submitted on 12 August 2016. The IDPR Annexure 7, common urban infrastructure, including technical investigations, concept engineering designs, drawings and cost estimates.
- The Civil Works Package: CW-02 (Zone A) – 1st Draft submitted on 13 December 2016. The package only included Volume I: Drawings and Volume III: Bill of Quantities (BoQ).

4. Following discussions during ADB Inception Mission (September 2016), the Master Plan was split into development zones. In the subsequent concept design report for common urban infrastructure for PTDP (Zone A) the water supply treatment plant for Zone A and B was moved from Zone B into Zone A.

5. PTDP's infrastructure design capacities used are based on the Phuentsholing Development Plan. PTDP's residential population projections are 16,280 for Zone-A and LAP area 4,100 a total of 20,380.

6. Technical due diligence has been undertaken based on the above outputs, observations made during the site visit undertaken in September 2016 and January 2017, and discussions and correspondence with CDCL.

2 Review Process

7. Review of the 2nd Draft IDPR and phase 1 (Zone A) concept design was undertaken in September 2016. Comments and recommendations were made to CDCL for review and appropriate action.

8. Comments on the 1st draft of the civil works package CW-02 (Zone A) were submitted to CDCL on 14th December 2016, and discussed with CDCL and their consultants.

9. Further design discussions between the PPTA, CDCL and their consultants were held in January and March 2017 to clarify and verify necessary phase 1 CUI design changes and civil works bidding documents.

3 Key Findings

3.1 General Bill of Quantity Issues

10. The first draft of the bill of quantities (BOQ) generally quoted Indian specifications. India's Ministry of Road Transport and Highways (MORTH) specifications might be suitable for roads and bridges but not for water supply and sewerage. Any standard that is not national should be clearly stated; ideally they should be internationally recognized.

11. The installation of power and telecommunication cables would be undertaken using Force Accounts by Bhutan Power Corporation (BPC) and Bhutan Telecommunications (BT) respectively. The BOQ therefore needs to be split into three parts in line with the required bid packages.

12. No general items were indicated in the BOQ. Although often included with FIDIC contracts, the common practice in South Asia is to include these costs within the item rates. The cost estimate summary included operation and maintenance at 7% of capital cost. The contract should include extended liability period and operation and maintenance ideally for five years, which should be priced by the bidding contractor.

3.2 Water Supply

13. The original concept was all five zones to be implemented as a single entity. The IDPR thus proposed a single raw water river intake with two water treatment plants designed to serve all four development zones.

14. The river intake located in the proposed river channelization would extract both surface and sub-surface water, depending on river water levels, connected by a buried delivery pipe to a jack-well sump on the left bank of Zone A. Access to the river intake was to be via a maintenance bridge from the left bank adjacent to the proposed jack-well. Raw water from the sump would then be pumped to treatment plants in Zone A (previously in Zone B) serving Zones A and B, adjacent to the jack-well and across the river via a new 2-lane road bridge, to a water treatment plant in Zone C (serving Zones C & E).

15. Concerns have been voiced that a previous river water intake was destroyed by high river flows in August 2000 which had operated for only about 2 years. Alternative locations for the river water intake could be considered, such as on the left bank directly downstream of Doyagang Bridge. In addition, long term options of using water by gravity from the proposed Amochhu hydro-power dam could also be explored.

16. The master plan design proposes gravity water supply from elevated water reservoirs. The reservoirs are designed as water towers although consideration had been given to locating the reservoirs on high ground to remove adverse visual effects. Unfortunately, for Zones A and B this would require land outside the project area, and therefore, during the detail design the location of tower will be selected in available government land. For Zone C locating a reservoir on Kaileshwar Hill is a possibility and could be considered during detail design for that future project phase.

17. However, due to financial constraints and the need for project phasing, an incremental approach that matches demand is required. With PTDP water supply limited to Zone A and the

adjacent Phuentsholing Thromde LAP[1] the revised concept design for PTDP uses ground water from 3 No. bore wells located within the water treatment plant compound. These deliver raw water to a ground storage reservoir (GSR) designed to cater for peak demand. This tank would be constructed with two compartments. One to store raw water and the other for treated water.

18. PTDP design includes a simplified water treatment plant with a capacity of 4.0 MLD comprising of pre-chlorination followed by pressure sand filters. However, the design allows for expansion to an 8.00 MLD conventional water treatment plant with a river raw water intake to cater for future development phases.

19. A hydro-boosting pressurized distribution system providing 24x7 water supply is proposed for phase 1 instead of elevated water towers. The LAP area would be served at one point with the minimum pressure of 1.20 Kg/cm². Local distribution to the individual plots within the LAP would be carried out by the Thromde.

20. PTDP treated water production capacity would likely exceed Zone A and LAP requirements for up to 10 years. Options to be considered include: a) develop and install bore wells as required (e.g. initially - one + stand-by; later – No.3 bore wells) or b) develop and install all 3 No. bore wells and sell surplus production to Phuentsholing Thromde.

21. However, although many households in the city core area only receive piped water for 6 hours per day this is mainly due to operations rather than supply capacity. The present Thromde borewells are only operated for 6 hours rather than the normal 20 hours per day apparently due to lack of funds to cover power charges for pumping. The Thromde has 9 borewells (installed after the 2000 flood destroyed the river intake) serving the city core near the Youth Development Centre, adjacent to Zone A. Six are operational, two are stand-by and one has a damaged pump.[2]

22. The proposed water treatment process, distribution and materials together with SCADA linked production and zonal water supply distribution metering for UFW[3] monitoring and management are appropriate but technical skills for operation and maintenance could be problematic.

23. With the lack of local skills an extended operation and maintenance period of five years[4] is proposed. This would include on-the-job training of future plant managers and operators. Beyond this, the owners (DHI) could either take over full control with its own staff or contract out the O&M either to the original contractor or to a new firm.

3.3 Sewerage and Wastewater Management

24. A separate system is proposed for the collection and treatment of wastewater. The IDPR master plan proposes 4 sewage treatment plants (STP) to serve all zones.

25. Zone C has two STPs. STP C-1 serves both Zone C (north) and Zone E and STP C-2 serves Zone C (south). Zone E, which might not be developed for some years, would have little sewage but requires a long trunk main to feed into STP C-1. Thus, it might be more economical

[1] LAP = Local Area Plan development area.
[2] Department of Engineering Services, MOWHS, May 2016, *Preparation of Water and Wastewater Master Plan for Phuentsholing Thromde*. Thimphu.
[3] UFW – unaccounted for water.
[4] 5 years proposed to be included in civil works contract, with 1 year under ADB during defects period and 4 under CDCL.

for the proposed resorts in Zone E to provide their own small sewage treatment package plant. With the adequate gradient through the project area STP-C1 could be deleted and all sewage in Zone C designed to gravitate to STP-C2 (enlarged) in the south. The released valuable land near the centre of the new development could then be used for greater financial return. The financial and economic pros and cons of alternatives should be clearly demonstrated in the Zone C final design.

26. The master plan indicates two STPs on the left bank, both located in Zone A; one at the north end to serve Zone B and the other on reclaimed land in the south next to the existing Phuentsholing Thromde STP. The latter is designed to serve phase 1 (Zone A plus LAP) with a capacity of 3.0 MLD. Flows from Zone B and the Torsa Tar area (located adjacent to Zone B) would gravitate to the STP at the north end of Zone A, located downstream of the proposed raw water river intake.

27. The sewage treatment process proposed is a sequential batch reactor (SBR) with automation and SCADA system to monitor operation. IDRP proposed a tertiary treatment facility. After treatment the water would be stored in a 12-hour capacity tank with an aeration facility to avoid stagnation. The treated water would be recycled for landscape irrigation with a micro irrigation system. Un-used water would be discharged into the river. The effluent quality standards would be frequently monitored. While this is commendable in principle, there is a public health risk regarding use of treated sewage effluent for irrigation in unrestricted public areas.

28. The STPs are designed to achieve a high standard of effluent: BOD < 5ppm, COD < 100 ppm, TSS < 10 ppm, in order to produce recyclable quality water for horticultural purposes. However, the required Bhutan NEC standard of effluent from STPs is only: BOD<50mg/l; TSS<100mg/l and Faecal coliform (MPN/100ml)<1000.

29. However, this high specification that is not required nationally adds to the technical complexity and cost. In addition, the selected SBR wastewater treatment technology with the high quality tertiary treatment might not be compatible with local conditions and skills for operation and maintenance. It is questioned whether the high capital and recurrent cost for such high quality water is warranted, and whether it provides the minimum carbon footprint. Based on these issues and in order to reduce costs, CDCL agreed that the tertiary treatment stage and effluent recycling system would be omitted from the phase 1 construction package.

30. As with the water supply system, due to the lack of local skills and experience an extended operation and maintenance period of five years is proposed. This would include on-the-job training of future plant managers and operators. Beyond this, the owners (DHI) could either take over full control with its own staff or contract out the O&M either to the original contractor or to a new firm.

31. The present sewerage system of Phuentsholing Thromde was commissioned in June 1996, financed by DANIDA and the government to serve the city core. The Thromde has extended the original sewerage coverage beyond the core and there are plans to provide separate sewerage for the whole of the city[5] eventually. The existing STP uses waste stabilisation ponds (WSP). This is a natural sewage treatment process requiring little or no power to operate. It is very efficient during the warm summer months but tends to emit odours during cooler weather.

[5] Department of Engineering Services, MOWHS, May 2016, *Preparation of Water and Wastewater Master Plan for Phuentsholing Thromde*. Thimphu.

However, it will require upgrading to a mechanised process in the coming years to allow the expansion of the sewerage network while also meeting the effluent standards required by NEC.[6]

32. Again, as with water supply, under PTDP there will be unutilized sewage treatment capacity for some years. This provides the opportunity for the Thromde to upgrade the existing STP by diverting flows during construction of a new STP to the PTDP STP. The option of totally combined operations under one organization could also be considered for the long-term operation of sewerage (and water supply) services.

3.4 Landscaping

33. Full designs should be completed as per CDCL TOR requirements. However, primarily due to financing constraints the main riverside park southern stretch will be only grass in the initial phase. This can be irrigated from hydrants placed along the embankment using flexible hoses and sprinklers fed from the proposed irrigation bore well. The latter is assumed to be located near the middle of the central embankment strip. Consequently, the original irrigation design layout using recycled water from the STP would need to be revised.

34. There could also be footpaths between the road and embankment joining to the toilet blocks. The toilet blocks could also house any irrigation equipment and horticultural tools.

35. A secondary reason for not completing the full landscaping, including gardens and play areas in Phase 1 is that for the first few years Zone A will be a sparsely occupied building site, and a safety risk for young children. Final landscaping could be considered for inclusion in future projects.

3.5 Roads and Stormwater Drainage

36. The right-of-way (ROW) of the Master Plan roads vary from 9m within neighbourhood zones to 40m for major arterial roads depending on the use and design capacity. The different uses and widths are discussed in the urban planning and design section of the report. All urban roads will be provided with LED street lighting and horticultural/tree planting.

37. Roads are designed with transverse and longitudinal gradient with side drains to collect and convey surface water to the main cross drains. The runoff from roads and premises is designed with a peak rain intensity of 100mm/hr. The surface water will be collected in a network of RCC pipes with diameters ranging from 450mm to 900mm. Inspection chambers will be located at maximum interval of 30m. These in turn would connect to the main stormwater cross drainage and river outfalls. Both the road side gullies and cross drainage should include silt traps which will require periodic cleaning and maintenance.

38. In the IRDP the streets have been designed to be typically made from M-30 grade cement concrete compared with compacted stone aggregate sealed with asphalt. Concrete surfacing has a slightly higher initial capital cost but a lower recurrent maintenance cost. Because of the difficulty of excavating through concrete road construction, buried utility services such as water supply, sewers, drainage, power and telecommunication cables and ducts are installed under the footpaths and not under the carriageway. During road construction, spare utility ducts are planned to be installed under the road at junctions to avoid the need for digging up the road in the future.

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[6] National Environment Commission, RGOB, November 2010. *Environmental Standards.* Thimphu.

3.6 Solid Waste Management (SWM)

39. The project has a zero-waste policy. The master plan includes solid waste processing facilities at two locations; at the southern end of both Zone A and Zone C. The facilities would include composting of 'wet' household organic kitchen/garden waste plus sorting, shredding, bailing etc. of 'dry' recyclable waste. One sanitary landfill area is proposed for the whole project for the disposal of un-recyclable reject material, in Zone-C, south of the STP and SWM processing facilities.

40. The treatment facility in Zone A has an ultimate design capacity of 8.0T/day. But the daily waste generation from the immediate phase will be only 2.0T wet and 1.0T dry waste.

41. The detail design for phase 1 construction therefore only includes the major treatment facilities of composting for wet waste and separation with compacting and bailing machinery for dry waste. However, space is allocated on the site for a bio-gas plant to treat hotel/restaurant bio-waste and STP sludge in the future when adequate demand develops.

42. The detail design 1st draft had omitted a) reception and weighbridge for recording collected waste; b) machinery for moving sorted waste around the solid waste treatment yard, e.g. fork lift; c) weighing scales for processed waste; or d) solid waste collection and transport equipment. These should be included in the final design.

43. In the long term Phuentsholing Thromde and PTDP SWM are considered to be separate operations. But the SWM system of PTDP could for many years be underutilized until housing and commercial development takes place.

44. Since Zone A will not include a sanitary landfill site all reject waste would need to be handed over to Phuentsholing Thromde for disposal. But the Thromde already has a problem of processing and disposing their present municipal solid waste (MSW). Consequently, CDCL could offer the PTDP SWM processing facilities to the Thromde, thus reducing the present volume of MSW going to the Thromde landfill site.

45. This arrangement would allow the Thromde to develop their own MSW processing facilities, including treatment and disposal facilities for medical and other hazardous wastes; which are not included in PTDP. Over time as the master plan develops and its own waste for processing increases, the waste from the Thromde would be decreased.

46. Separation of MSW into 2 streams at household level will require capacity building and public awareness in the 3R's[7] to implement effectively and efficiently. But this should be part of the SWM implementation contract package which could be over a longer operational period. This needs to be discussed and agreed with Phuentsholing Thromde and form part of CDCL's PTDP Management Plan.

3.7 Power Distribution, Street Lighting and Telecommunications

47. Power distribution. The power requirement for the residential area has been calculated on the basis of the IE norms, Bhutan Power rules and other appropriate standards.

[7] 3R's. Reduce, reuse and recycle.

48. The total power requirement for phase 1 (Zone A only, excluding the LAP), is estimated at about 8,500kVA. A 11kV underground power cable will be extended from a nearby substation to feed a 630kVA transformers for the initial phase (for three years). Ultimately a total of 9 transformers with 1,250kVA rating will need to be installed for Zone-A.

49. The main HT and LT underground feeders and sub-stations will be installed by Bhutan Power Corporation. Buried ducts will be provided at road junctions during road construction to avoid road digging for power and telecommunication cable installation at a later date.

50. Street lighting. All roads will be provided with LED street lights. LT lines for street lights will be laid underground along the footpaths in DWC pipe ducts. The positioning and type will be based on the road typology. Power saving measures will be used in the form of the timer based lighting system during low traffic hours (after 11:00PM) with alternate street lights in the OFF mode.

51. Telecommunications. The service level will be decided based on the existing communication infrastructure from the Tashi Cell and Bhutan Communication Department. The communication system from the Phuentsholing system in the nearby vicinity of Zone-A will be extended to fulfil the communication demand. The optical fibre network will be laid in PE pipes along all service corridors. Feeder pillars will be located at appropriate locations for connectivity to individual customers.

52. DWC Pipe (ISO 21138-3:2007) is proposed for all service ducting and non-pressure sewer pipes. It is suggested that different coloured pipes should be specified to distinguish between utilities.

3.8 Township Management Office

53. Part of the PTDP investment should include a Township Management Office building. This is necessary for marketing PTDP and for management of the project developed assets. The suggested location would be the first corner plot on entering Zone A.

4 Implementation

4.1 Review Process

54. The 1st draft CW-2 documents were received on 12 December 2016. PPTA reviewed the documents and provided comments and recommendations in table format to CDCL for review. The comments were discussed by a joint meeting between CDCL, their consultant, HCP and PPTA on 14 December 2016, in Thimphu.

55. The CW-2 designs were discussed further with CDCL and HCP in late January 2017 in Thimphu and various issued agreed. In early March an overview of the agreed urban planning and infrastructure changes was provided. In late March a preliminary BOQ was reviewed which reflected the agreed changes but no revised drawings or bidding documents were received.

4.2 Key Findings

56. The CUI civil works package will be procured using international competitive bidding using ADB's standard bid documents for large works, which use the *Conditions of Contract for*

Construction for Building and Engineering Works Designed by the Employer, Multilateral Development Bank Harmonized Edition, prepared by the Federation Internationale des Ingenieurs-Conseil or FIDIC (MDB Harmonized Construction Contract, June 2010).

57. Use of a FIDIC form of contract which requires an Employer's design, as proposed, requires the detailed design to be completed, the technical specifications to be thorough, the BoQ to be comprehensive, and drawings which are 'fit for construction'. It is a 'build and operate' contractual arrangement which puts the onus on the designer to fully document the design and identify the requirements for sustainable operations and maintenance of the assets.

58. *Drawings.* The 1st draft drawings reviewed in December 2016 were not complete but through discussion there was a clear intention to provide an appropriate level of detail. The 2nd draft, proposed to be provided in late May 2017, will require review before finalizing for bidding purposes.

59. *Technical specifications.* No complete set of specifications have been received for review, only references in the draft bill of quantities. For road works these appeared adequate, but were lacking in other sectors. These will require to be reviewed once received.

60. *Bill of Quantities.* The preliminary 2nd Draft BoQ was not logically set-out and not complete due to delay in finalizing urban planning and service demands. Review suggestions for improvement were provided by the PPTA.

61. *Design reports.* Detailed design for package CW-2 must be adequately documented. This is particularly important due to:

- the contractual split between the party responsible for the detailed design and the party responsible for the construction supervision, and
- the time between the end of detailed design and the start of construction.

62. It is recommended that design reports are produced for the various components/ systems, in line with normal practice, so that the key decisions are documented. This will be important during implementation when changes arise and the Project Implementation Consultant responsible for construction supervision is required to revisit the design to accommodate any changes. The design reports could be stand-alone documents or included as appendices to the IDPR. They should be consistent in terms of reporting the key design requirements, standards used, and calculations.

4.3 Conclusions

63. Based on review of the CW-2 (CUI - 1st draft) and those prepared for CW-1 (river works) the standard of the final drawings and specifications are expected to be adequate for use in bid documents based on a FIDIC MDB Harmonized Construction Contract. However, a thorough review of the designs and documents will be required before being used for contract bidding.