augmentation of water has already succeeded, much to the relief of the people of Badamash Pahar, Dollygunj, and Austinabad areas.

5.4.3 Water Supply and Sanitation

Augmentation of water supply to 10 villages was completed within two years after the tsunami. The Indira Nallah Water Supply Project and Chouldhari Water Supply Project are also in progress. The Indira Nallah project will provide 1.80 million liters of water per day to suburban areas of Port Blair. The Chouldhari Project will provide 4 million liters daily, part of which will be available to augment the water supply to the Chouldhari area, thus improving the water supply to the Cattlegunj, Tushnabad and Ograbranj areas.

Construction of the major trunk lines for the water supply/distribution system in Port Blair Municipal limits is at an advanced stage of completion. To augment the water supply to Port Blair and its suburban areas, raising the height of Dhanikhari Dam has been proposed. The techno-economic investigation for this project is being done by the NHPC. Implementing schemes to recharge the ground water at Guptapara and Lower Dhanikhari have been completed and are in progress at Long Island and Lalpahad areas.

5.4.4 Anti-Sea Erosion Measures

The coastline of the Andaman and Nicobar Islands is approximately 1,964 km long. Under the anti-sea erosion plan, about 800 m of sea wall was constructed during the eighth plan and 3,950 m of cement concrete sea wall was constructed during ninth plan. In the 10th plan about 12,250 m of sea wall is proposed to be constructed.

5.4.5 Locations of Damage

In Andaman and Nicobar, one of the main sources of drinking water is groundwater. Here both wells and soils were contaminated with salinity because of seawater ingress during the tsunami and due to tectonic subsidence.

A joint team of the Government of India Department of Drinking Water Supply and Ministry of Water Resources conducted an assessment of damages and drafting a restoration plan for the islands. As of February 2005, water supply was completely restored in Nancowry and Kamorta; 90% restored in Port Blair, South Andaman Rural, and Rangat; 80% in Mayabandar and Wimberlegunj; 60% each at Kadamtal and Degreepur; 50% at Campbell Bay; and 40 % Teressa. In Car Nicobar, nine wells were activated and 80% of the water supply restored through spring and wells. Natural water sources are available at Mildera and Beachdera, and 50% of the water supply was restored in Katchal. Out of three wells, one well was usable in Great Nicobar, and supply was partially restored through tankers. Wells and spring water are available in Little Andaman, and the water supply was partially restored. Repairs to remaining water supply systems were in progress as of February 2005.

In Nicobar, the Government of India Central Salt Research Institute has installed a reverse-osmosis (RO) unit in Car Nicobar, and the unit is treating brackish water with approximately 3,000 ppm total dissolved solids (TDS). Prior to the tsunami, this well was the source of drinking water. It is clear that the tsunami deteriorated the well's water quality. Even after two-weeks of operating the RO plant, the TDS has not come down.

In Campbell Bay, another RO unit was installed and was treating well water having 15,000 ppm salinity (Figure 5.4.5.1). This unit's capacity is 1,200 liters per hour (LPH) and is serving the needs of the entire island of 5,000 people. Here too, the damage from the tsunami was significant, and all wells were saline.

At the time of the investigation, no information was available on the soil's salinity or chloride concentrations. The soil chloride concentrations are likely very high in the A&N Islands since the inland water levels were increased approximately 1 meter after the tsunami and tectonic subsidence. High soil chloride concentrations inhibit vegetation and food crop growth. In addition, no one knows the long-term environmental and ecological effects of the tsunami and subsidence.

Figure 5.4.5.1. Reverse - osmosis plant at Campbell Bay in Andaman and Nicobar Islands. (Photo by ASCE/TCLEE/EIC team.)

5.4.6 Water Mains along South Andaman Island Trunk Road

The 18-inch diameter reinforced concrete water lines that were laid parallel to the main trunk road on South Andaman Island were damaged as a result of ground shaking, ground settlement, and the tsunami. Note that six weeks after the earthquake, the pipeline was still leaking at the joints (Figure 5.4.6.1).

Figure 5.4.6.1. Water main leaking along South Andaman Island Trunk Road. (Photo by ASCE/TCLEE/EIC team.)

5.4.7 Sluice Gates along South Andaman Island Trunk Road

A number of sluice gates under the South Andaman Island Trunk Road were built to drain the rice fields and control infiltration of seawater. During the earthquake, however, the tsunami overtopped the roads and broke the sluice gates (Figure 5.4.7.1). Moreover, the eastern part of South Andaman Island suffered tectonic subsidence as a result of the earthquake and the land has become permanently inundated with salt water, destroying the rice fields that were ready for harvest (Figure 5.4.7.2).

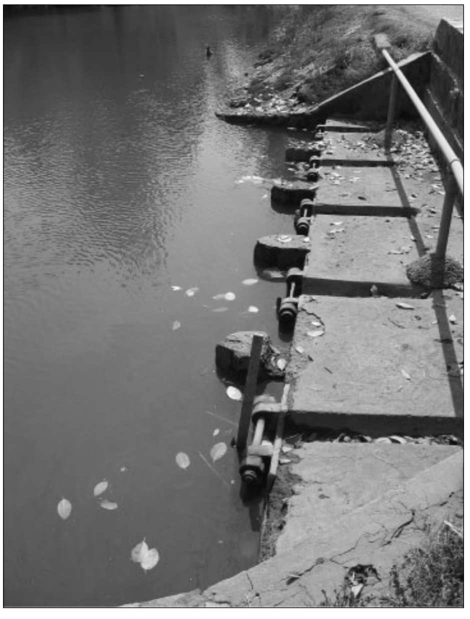

Figure 5.4.7.1. Damaged sluice gates under Andaman Island Trunk Road. (Photo by ASCE/TCLEE/EIC team.)

Figure 5.4.7.2. Fields in South Andaman Island were inundated by sea water. (Photo by ASCE/TCLEE/EIC team.)

5.4.8 Watersheds for Port Blair in South Andaman Island

The main water source for Port Blair is the watershed behind the Dhanikhari Dam. This water retention structure on the Dhanikhari River was constructed from 1970 to 1973 to supply water to Port Blair. The dam is a 132 m long and 32.23 m high straight gravity-concrete structure with a central gated spillway. The reservoir extends to an area of 0.49 by 10 square miles, and the storage capacity is approximately 9,000 liters. On December 26, 2004, the reservoir water level was 60.60 m. Inspection of the dam revealed some minor distress to the main structure from the earthquake. The development of fine cracks and chipping of plaster along two of the right abutment block joints was visible. Inspection of the foundation gallery showed cracking of the RCC along the fifth block joint, through which a considerable amount of seepage was occurring. Some minor seepage was also coming from the right abutment slopes of the gallery. It was reported that, prior to the earthquake, the water collecting in the foundation gallery used to be pumped after every six hours. After the earthquake and due to the increased seepage, which required hourly pumping. The reservoir water was also considerably agitated due to the passage of the shock waves as manifested by the seiche (standing water waves), which rose by as much as 3 to 4 m. After the earthquake, the main supply pipes were dislodged, and therefore in the initial days following the earthquake, the water supply to the town remained disrupted.

The Chouldari watershed is a 19-m high and 95-m long earthen dam structure with a 10-m wide and 80.58-m long left bank with an ungated reinforced concrete chute spillway. The earthen section has pitching of basalt blocks, both in the upstream and downstream sides. A concrete apron has been placed over the entire length of the crest. At the junction of the earthen section and spillway concrete, the concrete apron buckled as much as 8 cm along the block joint. It was reported that on the morning of the earthquake the reservoir level (reservoir area 15 ha) was quite low. Due to the tremors, however, the waves in the reservoir splashed onto the crest portion about 5.6 m above the reservoir level.

5.4.9 Elevated Water Tanks

Several elevated water tanks were damaged due to ground shaking. Figure 5.4.9.1 shows a masonry structure with no footing that had a bearing failure of the supporting soil during the earthquake. If not for the concrete well built in front of it, it would have tipped over. A submersible pump filled the 200 gallon tank at the top of the structure.

Figure 5.4.9.1. Elevated water tank at Port Blair, South Andaman Island.
(Photo by ASCE/TCLEE/EIC team.)

A large reinforced concrete tank with under reinforced columns and connections had serious damage but did not collapse during the earthquake. The TCLEE/ASCE investigation team also saw several well-designed, inverted, cone-shaped, elevated water tanks that performed well during the ground shaking and tsunami.

5.4.10 Observations and Recommendations

1. Reinforced concrete water supply storage tanks were relatively unaffected by the tsunami seawater waves. Most of the observed damage came from ground shaking.
2. The main problem was well and soil contamination due to seawater ingress during the tsunami. The affect of seawater from the tsunami on surface soils was not known at the time of the investigation. This problem was exacerbated by tectonic subsidence that put many islands partially under seawater.
3. The government administrators for the Territory of the Andaman and Nicobar Islands took adequate measures to provide temporary drinking water supplies to the affected villages and towns.
4. The long-term effects of the tsunami and tectonic subsidence on the environment and ecology must be investigated.

Notes

1 Task Force for Rebuilding the Nation (TAFREN), 2005. "Rebuilding Sri Lanka: Action plan," Sri Lanka Department of National Planning, Discussion draft, p. 5. (http://www.tafren.gov.lk/docs/ActionPlanDraft.pdf)

2 PAFFREL, 2005. "Post-tsunami rehabilitation and reconstruction, progress report—April 15, 2005," in Report on monitoring services to tsunami victims for the month of May 2005," Annex VI. (http://www.lankaworld.com/paffrel/Publications/4th_Interim_Report.pdf#search='paffrel%20interim%20report%20May%202005')

3 Asian Development Bank, Japan Bank for International Cooperation, and World Bank, 2005. "Sri Lanka 2005 post-tsunami recovery program, Preliminary damage and needs assessment," January 28, 2005. (http://www.adb.org/Documents/Reports/Tsunami/sri-lanka-tsunami-assessment.pdf)

4 District Disaster Management Center, Division Secretariat, Hambantota, 2005. "Tsunami disaster 26, December 2004, Hambantota District: Damage assessment and action plan," March 7, 2005, 56 pp. (http://www.humanitarianinfo.org/srilanka/infocentre/assessments/others/doc/District_Disaster_Mgmt_Center_Hambatota/Damage%20Assesment%20&%20Action%20Plan_Hambantota.pdf)

5 Fernando, M., and Kumarasinghe, U., 2004. "Tidal wave death toll in Sri Lanka over 10,000," in Daily News, December 28, 2004. (http://www.dailynews.lk/2004/12/28/new01.html)

6 Salzmann, U., and Schwager, C., 2004. "Rapid assessment Matara district," December 30, 2004, Swiss Humanitarian Aid Rapid Assessment Team, Embassy of Switzerland. (http://www.humanitarianinfo.org/srilanka/infocentre/assessments/others/doc/SHA/SHA_Rapid_Assessment_Matara.pdf)

7 Palakidnar, A., 2005. "India's goodwill gesture: Bridge on the Arugambay," in Sunday Observer, March 20, 2005. (http://www.sundayobserver.lk/2005/03/20/fea24.html)

8 India HCSL, 2005. "'Bond of brotherhood established by good deeds' of Indian Army composite disaster relief team in Galle District, 'will be in our hearts forever' says Galle District Secretary," Press Release PR/7, February 14, 2005. (http://www.indiahcsl.org/press_releases.htm)

9 Asian Development Bank, Japan Bank for International Cooperation, and World Bank, 2005. "Rebuilding Sri Lanka: Assessment of Tsunami Recovery Implementation (JNA Phase II Assessment)," July 21, 2005, 129 pp. (http://www.humanitarianinfo.org/srilanka/infocentre/assessments/others/doc/ADB_JBIC_WB_Gov/ADB_JBIC_WB_Gov.pdf)

10 Asian Development Bank, Japan Bank for International Cooperation, and World Bank, 2005. "Sri Lanka 2005 post-tsunami recovery program, Preliminary damage and needs assessment," January 28, 2005. (http://www.adb.org/Documents/Reports/Tsunami/sri-lanka-tsunami-assessment.pdf)

11 Asian Development Bank, Japan Bank for International Cooperation, and World Bank, 2005. "Sri Lanka 2005 post-tsunami recovery program, Preliminary damage and needs assessment," January 28, 2005. (http://www.adb.org/Documents/Reports/Tsunami/sri-lanka-tsunami-assessment.pdf)

12 Asian Development Bank, Japan Bank for International Cooperation, and World Bank, 2005. "Sri Lanka 2005 post-tsunami recovery program, Preliminary damage and needs assessment," January 28, 2005. (http://www.adb.org/Documents/Reports/Tsunami/sri-lanka-tsunami-assessment.pdf)

13 "Immediate action to restore basic water supply facilities," in Daily News, January 6, 2005. (http://tsunamihelp.blogspot.com/2005/01/immediate-action-to-restore-basic.html#110501759288727464)

14 Wickramage, F., 2005. "Water board cleans wells in tsunami areas," in Daily News, January 22, 2005. (http://www.dailynews.lk/2005/01/22/new46.html)

15 Wickramage, F., 2005. "Water board cleans wells in tsunami areas," in Daily News, January 22, 2005. (http://www.dailynews.lk/2005/01/22/new46.html)

16 International Committee of the Red Cross, 2005. "Sri Lanka bulletin No. 2—9 February 2005, Latest report on ICRC activities in the field." (http://www.icrc.org/Web/Eng/siteeng0.nsf/html/69GHP4)

17 International Committee of the Red Cross, 2005. "Sri Lanka bulletin No. 3—18 February 2005, Latest report on ICRC activities in the field." (http://www.icrc.org/Web/Eng/siteeng0.nsf/html/69QNRP)

18 International Committee of the Red Cross, 2005. "Tsunami disaster in Sri Lanka, the response of the International Committee of the Red Cross," March 14, 2005. (http://www.humanitarianinfo.org/srilanka/infocentre/sitreps/docs/ICRCBulletin5.pdf)

19 International Committee of the Red Cross, 2005. "Sri Lanka bulletin No. 3—18 February 2005, Latest report on ICRC activities in the field." (http://www.icrc.org/Web/Eng/siteeng0.nsf/html/69QNRP)

20 International Committee of the Red Cross, 2005. "Tsunami disaster in Sri Lanka, the response of the International Committee of the Red Cross," March 14, 2005. (http://www.humanitarianinfo.org/srilanka/infocentre/sitreps/docs/ICRCBulletin5.pdf)

21 International Committee of the Red Cross, 2005. "Tsunami disaster in Sri Lanka, the response of the International Committee of the Red Cross," March 14, 2005. (http://www.humanitarianinfo.org/srilanka/infocentre/sitreps/docs/ICRCBulletin5.pdf)

22 International Committee of the Red Cross, 2005. "Sri Lanka bulletin No. 4—25 February 2005, Latest report on ICRC activities in the field." (http://www.icrc.org/Web/Eng/siteeng0.nsf/html/69XEAZ)

23 International Committee of the Red Cross, 2005. "Tsunami disaster in Sri Lanka, the response of the International Committee of the Red Cross," March 14, 2005. (http://www.humanitarianinfo.org/srilanka/infocentre/sitreps/docs/ICRCBulletin5.pdf)

24 International Committee of the Red Cross, 2005. "Tsunami disaster in Sri Lanka, the response of the International Committee of the Red Cross," March

14, 2005. (http://www.humanitarianinfo.org/srilanka/infocentre/sitreps/docs/ICRCBulletin5.pdf)

25 International Committee of the Red Cross, 2005. "Tsunami disaster in Sri Lanka, the response of the International Committee of the Red Cross," March 14, 2005. (http://www.humanitarianinfo.org/srilanka/infocentre/sitreps/docs/ICRCBulletin5.pdf)

26 International Committee of the Red Cross, 2005. "Sri Lanka bulletin No. 4—25 February 2005, Latest report on ICRC activities in the field." (http://www.icrc.org/Web/Eng/siteeng0.nsf/html/69XEAZ)

27 Russell, S, 2005. "Jury-rigged ferry service links devastated village to food, water supplies," in SF Gate, January 25, 2005. (http://sfgate.com/cgi-bin/article.cgi?file=/c/a/2005/01/25/MNG08AVRJP1.DTL)

Karadjias, P., 2005. AP Photo, January 8, 2005.

28 "Canadians quench thirst, ease trauma of Sri Lankan tsunami survivors," AFP, February 3, 2005. (http://news.yahoo.com/news?tmpl=story&cid=1535&u=/afp/asiaquakesrilankacanadamilitary&printer=1)

29 BEM Systems, Inc., 2005. "Assuring clean, safe water supplies for tsunami ravaged towns," in Water and Wastes Digest, March 28, 2005. (http://www.wwdmag.com/wwd/index.cfm/powergrid/rfah=|cfap=/CFID/3390642/CFTOKEN/41873202/fuseaction/showNewsItem/newsItemID/8914)

30 "Tsunami update: ITT's quick response in Sri Lanka yields quicker results," in Pennnet, January 24, 2005. (http://ww.pennnet.com/articles/article_display.cfm?article_id=219936)

31 "Water industry aids tsunami relief," in Oil and Gas Journal. (http://ogj.pennnet.com/Articles/Article_Display.cfm?Section=ARTCL&ARTICLE_ID=227607&VERSION_NUM=3&p=20)

32 Wolfe, P., 2005. "Water industry aids tsunami relief," in "Tsunami recovery costs $1.5 billion in Sri Lanka," in Oil & Gas Journal, February 2005. (http://ogj.pennnet.com/Articles/Article_Display.cfm?Section=ARTCL&ARTICLE_ID=227607&VERSION_NUM=3&p=20)

33 Searing, N., 2005. "Tsunami: How our industry responded," in Water Conditioning & Purification, April 2005. (http://www.wcp.net/PDF/0405%20Tsunami%20response.pdf)

34 BEM Systems, Inc., 2005. "Assuring clean, safe water supplies for tsunami ravaged towns," in Water and Wastes Digest, March 28, 2005. (http://www.wwdmag.com/wwd/index.cfm/powergrid/rfah=|cfap=/CFID/3390642/CFTOKEN/41873202/fuseaction/showNewsItem/newsItemID/8914)

35 Seacoast Church, 2005. "Water Missions International: saving lives, changing hearts." (http://www.seacoast.org/mountpleasant/missions/wmi.html)

36 "Tsunami update: ITT's quick response in Sri Lanka yields quicker results," in Pennnet, January 24, 2005. (http://ww.pennnet.com/articles/article_display.cfm?article_id=219936)

37 Searing, N., 2005. "Tsunami: How our industry responded," in Water Conditioning & Purification, April 2005. (http://www.wcp.net/PDF/0405%20Tsunami%20response.pdf)

38 Searing, N., 2005. "Tsunami: How our industry responded," in Water Conditioning & Purification, April 2005. (http://www.wcp.net/PDF/0405%20Tsunami%20response.pdf)

39 "Tsunami update: ITT's quick response in Sri Lanka yields quicker results," in Pennnet, January 24, 2005. (http://ww.pennnet.com/articles/article_display.cfm?article_id=219936)

40 International Committee of the Red Cross, 2005. "Sri Lanka bulletin No. 1—31 January 2005, ICRC's activities on behalf of the tsunami victims." (http://www.icrc.org/Web/Eng/siteeng0.nsf/htmlall/697CKF)

41 International Committee of the Red Cross, 2005. "Sri Lanka bulletin No. 2—9 February 2005, Latest report on ICRC activities in the field." (http://www.icrc.org/Web/Eng/siteeng0.nsf/html/69GHP4)

42 United Nations Joint Logistics Centre, 2005. "January—Weblog—Sri Lanka," Entry for January 6, 2005. (http://www.unjlc.org/content/index.phtml/itemId/31119?pageDefinitionItemId=11296)

43 United Nations Joint Logistics Centre, 2005. "January—Weblog—Sri Lanka," Entry for January 22, 2005. (http://www.unjlc.org/content/index.phtml/itemId/31119?pageDefinitionItemId=11296)

44 "French water agency helps NWS&DB to restore water supply to Kinniya," in Daily News, May 13, 2005. (http://www.dailynews.lk/2005/05/13/news23.htm)

45 Asian Development Bank, Japan Bank for International Cooperation, and World Bank, 2005. "Assessment of the tsunami recovery implementation in Batticaloa District," in "Rebuilding Sri Lanka: Assessment of Tsunami Recovery Implementation (JNA Phase II Assessment)," July 21, 2005, 129 pp. (http://www.humanitarianinfo.org/srilanka/infocentre/assessments/others/doc/ADB_JBIC_WB_Gov/ADB_JBIC_WB_Gov.pdf)

46 United Nations Office for the Coordination of Humanitarian Affairs, 2005. "Humanitarian situation in Sri Lanka, Situation report, Reporting period: 18—24 March 2005." (http://www.humanitarianinfo.org/srilanka/catalogue/Files/InfoCentre/Sitreps/OCHA/SR_SriLanka_OCHA_Humanitarian_Situation_Report18-24%20March%20%20PDF.pdf)

47 Asian Development Bank, Japan Bank for International Cooperation, and World Bank, 2005. "Assessment of the tsunami recovery implementation in Batticaloa District," in "Rebuilding Sri Lanka: Assessment of Tsunami Recovery Implementation (JNA Phase II Assessment)," July 21, 2005, 129 pp. (http://www.humanitarianinfo.org/srilanka/infocentre/assessments/others/doc/ADB_JBIC_WB_Gov/ADB_JBIC_WB_Gov.pdf)

48 United Nations Office for the Coordination of Humanitarian Affairs, 2005. "Humanitarian situation in Sri Lanka, Situation report, Reporting period: 18—24 March 2005." (http://www.humanitarianinfo.org/srilanka/catalogue/Files/InfoCentre/Sitreps/OCHA/SR_SriLanka_OCHA_Humanitarian_Situation_Report18-24%20March%20%20PDF.pdf)

49 Ruiz, T., 2005. "Sri Lanka: A silent witness to destruction and progress," in "Tsunami disaster—countries in crisis," by UNICEF, June 23, 2005. (http://www.unicef.org/emerg/disasterinasia/24615_27487.html)

50 Ruiz, T., 2005. "Sri Lanka: A silent witness to destruction and progress," in "Tsunami disaster—countries in crisis," by UNICEF, June 23, 2005. (http://www.unicef.org/emerg/disasterinasia/24615_27487.html)

51 "Giant Korean water project for south in Sri Lanka," in Tsunami-Recovery.net, May 12, 2005. (http://www.tsunami-recovery.net/content/view/147/60/)

52 Russell, S, 2005. "Jury-rigged ferry service links devastated village to food, water supplies," in SF Gate, January 25, 2005. (http://sfgate.com/cgi-bin/article.cgi?file=/c/a/2005/01/25/MNG08AVRJP1.DTL)

53 "World Vision tsunami response July/August update," August 15, 2005. (http://www.relliefweb.int/rw/rwb.nsf/db900SID/KHII-6FA8Z3?OpenDocument&rc=3&cc=tha)

54 "Metrowater drive to provide safe drinking water," in The Hindu, January 4, 2005. (http://www.the hindu.com/2005/01/05/stories/2005010512770300.htm)

55 Ramakrishnan, T., 2005. "Water supply in Cuddalore, Nagapattinam to be restored soon," in The Hindu, January 2, 2005. (http://www.the hindu.com/2005/01/03/stories/2005010305300400.htm)

56 Ramakrishnan, T., 2005. "Water supply in Cuddalore, Nagapattinam to be restored soon," in The Hindu, January 2, 2005. (http://www.the hindu.com/2005/01/03/stories/2005010305300400.htm)

57 Ramakrishnan, T., 2005. "Water supply in Cuddalore, Nagapattinam to be restored soon," in The Hindu, January 2, 2005. (http://www.the hindu.com/2005/01/03/stories/2005010305300400.htm)

58 Ramakrishnan, T., 2005. "Water supply in Cuddalore, Nagapattinam to be restored soon," in The Hindu, January 2, 2005. (http://www.the hindu.com/2005/01/03/stories/2005010305300400.htm)

59 "Water treatment plants in tsunami-hit villages," in The Hindu, January 16, 2005. (http://www.the hindu.com/2005/01/17/stories/2005011703060300.htm)

60 "Seawalls to get priority," in The Hindu, January 3, 2005. (http://www.the hindu.com/2005/01/04/stories/2005010411760300.htm)

61 Subramanian, K., 2005. "Army constructing causeway, retrieving boats," in The Hindu, January 5, 2005. (http://www.the hindu.com/2005/01/06/stories/2005010607640400.htm)

62 World Vision, 2005. "World Vision tsunami response July/August 2005 update," August 15, 2005. (http://www.reliefweb.int/rw/rwb.nsf/db900SID/KHII-6FA8Z3?OpenDocument&rc=3&cc=tha)

63 Ole, P. P., 2005. "Detailed report on April visit to tsunami area," in Tulsa Mid Town Rotary Club2 Tsunami Relief Project. (http://www.tulsamidtownrotary.com/status_2005.html)

This page intentionally left blank